United States
Department of
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**Pacific
Northwest
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Plant Association and Management Guide for the Western Hemlock Zone

Gifford Pinchot National Forest

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Plant Association and Management Guide for the Western Hemlock Zone

Gifford Pinchot National Forest

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CONTENTS

CHAPTER 1 INTRODUCTION

Introduction

Plant associations are groupings of plant species which reoccur on the landscape within particular environmental tolerances. Knowledge of plant associations can greatly aid land managers to "read" and understand environmental variability. This leads to more accurate treatment response prediction and analysis of resource potential.

Associations can serve as particularly useful tools for the land manager:

(1) by indicating environmental features of sites;
(2) by providing greater site specificity and applicability when communicating research results and management experience;
(3) by predicting management response and better prescription of suitable activities;
(4) by serving as a natural inventory system of land resources.

This guide presents the plant association classification for the Western Hemlock Zone of the Gifford Pinchot National Forest. The bulk of the Forest below about 3000 feet in elevation is included in this zone, comprising about one half of the entire land base. Much of this area is blanketed with productive stands of Douglas-fir.

What is the Western Hemlock Zone?

The Western Hemlock Zone is biologically defined as those lands where western hemlock is expected to be the dominant tree species given an opportunity to achieve a long-term stable state. In practice, it includes areas where western hemlock is the primary regenerating tree species in mature stands. The Western Hemlock Zone is further delineated by the relative lack of regeneration by tree species which indicate harsher environments: Pacific silver fir, mountain hemlock and subalpine fir at higher elevations and Douglas-fir, grand fir and Oregon white oak on drier sites.

What is in this guide?

This guide is designed to present and to document the properties of Western Hemlock Zone plant associations. This chapter first discusses classification concepts which help explain fundamental terminology and biological processes. We then outline our study methods and highlight some of the uses of this association classification. Chapter two provides an ecosystem perspective to the chief factors affecting the vegetation resource. This includes an overview of the entire Western Hemlock Zone, and more detailed presentations on physical (climate, geology, soils) and biological (forest floor, snag and fallen tree, forage, and timber) properties of the plant associations.

The dichotomous key to plant associations in Chapter 3 helps us determine the particular association present at any given site. Detailed descriptions form the body of this guide (Chapter 4). They are the basic reference to the classification system and should always be consulted before designating the association at a locale.

Plant Association Names and Ecoclass Codes

Plant associations are complex groupings of plant species. We name associations after the more prominent tree, shrub or herb species present in mature stands. The named species are usually those characteristic of a particular environment: they need not be the most abundant species present. We have tried to use common English names for all species. The associations are more conveniently referenced by the 4 letter computer codes derived from the Latin names (Garrison et al. 1976). This shorthand system is very useful for regular users. Casual users of the plant association classification system should not be scared off by this jargon; it can be avoided if you so wish. Major tree, shrub and herb species are listed in Table 17 by their common, Latin and code names.

Plant association designations are coordinated within the Pacific Northwest Region (R6) of the Forest Service by the Regional Ecologist. Associations are given specific Ecoclass codes (Hall 1984) which form the basis of documenting the land base with the Total Resource Information (TRI) systems on each National Forest.

The plant associations and their distributions are listed in Table 1. Throughout this guide the order of the associations follows an approximate moisture gradient from wet to dry.

Table 1. Names, abbreviations, Ecoclass codes and general geographic locations of the Western Hemlock Zone Plant Associations of the Gifford Pinchot National Forest.

PLANT ASSOCIATION	SCIENTIFIC NAME	ABBREVIATION	ECOCLASS CODE	GEOGRAPHIC LOCATION
Wet Group:				
Western hemlock/ Skunk-cabbage	Tsuga heterophylla/ Lysichitum americanum	TSHE/LYAM	CHM1-21	saturated sites, GP and MH NF's
Western hemlock/ Ladyfern	Tsuga heterophylla/ Athyrium filix-femina	TSHE/ATFI	CHF4-21	very moist sites, west and north ends of GP
Western hemlock/ Devil's Club/ Swordfern	Tsuga heterophylla/Oplopanex horridum/Polystichum munitum	TSHE/OPHO/POMU	CHS5-24	very moist sites, especially west side of GP NF
Moist group:				
Western hemlock/ Swordfern-Oregon Oxalis	Tsuga heterophylla/Polystichum munitum-Oxalis oregana	TSHE/POMU-OXOR	CHF1-24	moist sites, mostly lower elevations, GP and MH NF's
Western hemlock/ Alaska huckleberry/Oregon oxalis	Tsuga heterophylla/ Vaccinium alaskaense/Oxalis oregana	TSHE/VAAL/OXOR	CHS6-13	western edge of GP and mid elev of Bull Run, MH NF
Western hemlock/ Coolwort foamflower	Tsuga heterophylla/ Tiarella trifoliata	TSHE/TITR	CHF2-22	moist sites, higher elev TSHE zone, west side of GP NF
Western hemlock/ Swordfern	Tsuga heterophylla/ Polystichum munitum	TSHE/POMU	CHF1-25	moist sites, lower slopes widespread; GP type
Mesic group:				
Western hemlock/Dwarf Oregon grape/Swordfern	Tsuga heterophylla/Berberis nervosa/Polystichum munitum	TSHE/BENE/POMU	CHS1-26	very widespread, mesic sites GP and MH NF's

PLANT ASSOCIATION	SCIENTIFIC NAME	ABBREVIATION	ECOCLASS CODE	GEOGRAPHIC LOCATION
Mesic group (cont.):				
Western hemlock/ Alaska huckleberry/dogwood bunchberry	Tsuga heterophylla/Vaccinium alaskaense/Cornus canadensis	TSHE/VAAL/COCA	CHS6-15	higher elevations of TSHE zone GP and MH NF's
Western hemlock/ Alaska huckleberry- Salal	Tsuga heterophylla/Vaccinium alaskaense-Gaultheria shallon	TSHE/VAAL-GASH	CHS6-14	higher elevations of TSHE zone GP and MH NF's
Western hemlock/ Vanilla-leaf	Tsuga heterophylla/ Achlys triphylla	TSHE/ACTR	CHF2-21	widespread throughout TSHE zone, GP and MH NF's
Western hemlock/ Dwarf Oregon grape	Tsuga heterophylla/ Berberis nervosa	TSHE/BENE	CHS1-25	higher elevations of TSHE zone upper slopes, GP and MH NF's
Western hemlock/ Dwarf Oregon grape-salal	Tsuga heterophylla/Berberis nervosa-Gaultheria shallon	TSHE/BENE-GASH	CHS1-27	widespread but more on east GP ridges and upper slopes
Dry group:				
Western hemlock/ Salal	Tsuga heterophylla/ Gaultheria shallon	TSHE/GASH	CHS1-28	more on east TSHE zone, ridges and upper slopes
Western hemlock/ Dogwood/ Vanilla-leaf	Tsuga heterophylla/Cornus nuttallii/Achlys triphylla	TSHE/CONU/ACTR	CHS2-24	southern GP NF, south slopes lower elevations
Western hemlock-Douglas-fir/ Oceanspray	Tsuga heterophylla-Pseudotsuga menziesii/Holodiscus discolor	TSHE-PSME/HODI	CHC2-12	ridges, S slopes, SE GP TSHE zone, cliffs on MH NF
Western hemlock-Douglas-fir-Madrone	Tsuga heterophylla-Pseudotsuga menziesii-Arbutus menziesii	TSHE-PSME-ARME	CHC2-13	rock outcrops, especially above Cowlitz River Valley

Plant Associations as Indicators of Environment

A mountain ecosystem is a mosaic of different environments, each having its own unique physical and biotic characteristics. Plant communities that occupy these different sites are a function of the land's topography, geology, climate, herbivorous animals and those which disperse seeds, pathogens, and the habitat requirements of the plants available to vegetate the land.

In a sense, the environment acts as a screen (illustrated in Fig. 1) to prevent reproductive success of species unsuited to a given site. In a typical stream drainage for instance, seed from a wide variety of plants makes up the "seed rain" that falls on a given piece of ground. In extremely hot, cold, wet, dry or nutrient-poor sites, only those species that can tolerate such conditions survive to reproduce themselves. On the other hand, where more moderate conditions prevail, a larger number of species is able to reproduce, and competitive ability becomes more important in determining which species eventually become dominant.

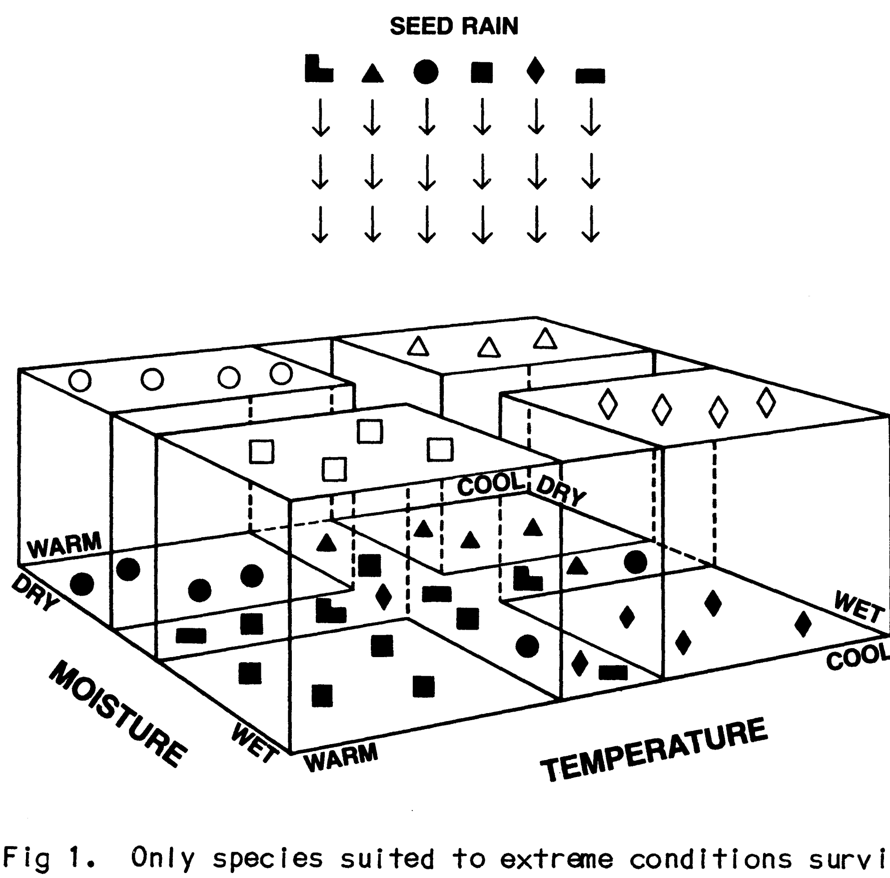

Fig 1. Only species suited to extreme conditions survive and reproduce in environments at the ends of moisture and temperature gradients.

An extremely important concept follows from this perception of the environment as a screen to reproductive success: **Areas with an equivalent environment will, in general, eventually support roughly the same combination of plant species.** A corollary concept is that **the group of species that eventually becomes dominant on a site acts both as an _indicator_ of environmental conditions, and as a _means of comparing_ different sites to each other.** For these reasons, plant associations can be seen as one important tool in the prediction and control of effects of forest management activities.

Association Boundaries: In Space and Time

It's fairly easy to see that plant associations have boundaries in **space**, since soil characteristics, topography and climate vary across the landscape. In most forested areas boundaries between areas having different plant associations are quite gradual, because environmental conditions change slowly over a relatively long distance. This often makes mapping distinct lines between communities virtually impossible. This "continuum" nature of vegetation on the west slope of the Cascades must be recognized by anyone trying to use this guide. There are many stands where the vegetation is transitional between two or more plant associations, and a judgment must be made as to which description fits best. These sites may be treated by mixing the management recommendations of the different types.

It is also true that plant communities have boundaries in **time.** Groups of different plant species succeed each other over time on a particular piece of ground because the physical and biological conditions of the land change temporally as well as spatially.

For example, in managed forests there are many different-aged communities of herbs and shrubs giving way to new stands of trees. As a young stand of trees grows, the ground surface becomes increasingly shaded and many light-loving species are eliminated from the plant community because they cannot perpetuate themselves.

As this development of vegetation in a disturbed area progresses, eventually the species composition stabilizes into a community that reproduces itself, rather than being replaced by something else. This ultimate community, which prevails unless it is disturbed again, is called the **_climax plant community_**, or **_plant association_**, and the process of different communities replacing each other until the climax community is reached is called **succession**. The plant communities that precede the climax association are called **seral stages**. Some readers may be familiar with the term **habitat type**. It is used to refer to the combination of a plant association and the physical/climatic habitat in which it occurs (Pfister et al. 1977). A **zone** is the area within which a particular tree species is the stand dominant in the climax plant community. For example, the Western Hemlock Zone encompasses forests where western hemlock would eventually dominate the overstory (assuming no disturbance takes place). Forests that today have Douglas-fir in the overstory with western hemlock in the understory are considered to be within the Western Hemlock Zone because the Douglas-fir is not reproducing itself, while western hemlock is.

Plant associations for forested areas must initially be identified in mature stands, since that is where the vegetation has more or less stabilized. In many cases, however, the climax plant association for earlier seral stages can be inferred from the presence of indicator plants. By this means, environmentally equivalent areas can be identified even though they may be at different places on the successional route. Conversely, the composition of seral stages can often be predicted from the climax plant association, making it possible to know whether undesirable species are likely to be present following disturbance.

The complex of associations or communities that occur within a zone can be referred to as a series. Often we use the terms zone and series interchangeably, though "series" describes a group of associations and "zone" the land on which the associations occur. A similar relationship exists between the terms "habitat type" and "plant association" as exists between "zone" and "series".

Vegetation zones are of interest because they generally represent major large-scale climatic differences within a region. A discussion of the forest zones found on the Gifford Pinchot National Forest is presented in Chapter 3 of this guide.

Intergradation among associations is most pronounced in the transition area between the forest zones (i.e., Western Hemlock Zone/ Pacific Silver Fir Zone transition). We do not describe separate transition zones, as do some authors. The simplicity of our system requires flexibility by users working in the transition area between forest zones.

Methods

The classification is based on a relatively standard vegetation analysis procedure of our study plots established throughout the Gifford Pinchot National Forest. Our sampling scheme involves selecting undisturbed stands which include the natural vegetation variation found within the Western Hemlock Zone. These plots are in stands preferably at least 60 years old so the understory vegetation has had some time in which to become established and reflect the future potential of the site. We measured percent cover of all vascular plant species within 500 m^2 plots. We also collected detailed information on timber, soils and wildlife features of the plot area; techniques for each are mentioned separately in Chapter 2. Figure 2 displays the distribution of our plots. Appendix 1 provides a detailed breakdown of plots in each association by Ranger Districts, township and range.

The association classification is the result of a dynamic interaction between subjective and objective multivariate statistical procedures. We tested initial plot ordering results (Volland and Connelly 1978) with results from detrended correspondance analysis (DECORANA) (Gauch 1977 plus supplements; Gauch 1982). Two-step indicator species analysis (TWINSPAN) was used to examine the classification value of various species and plot groups. Results were checked to re-order the subjective association groupings. Old-growth plots were more heavily weighted as they better reflect the eventual floristic composition which define associations. Preliminary keys were field-tested and the final classification modified. We carefully compared final association classifications of different National Forests. Nine associations were identical between the Gifford Pinchot and Mt. Hood National Forests, so combined data are presented for these types (see Halverson et al. 1986). These associations (2 of which are very uncommon on the G.P.) are listed in Appendix 3.

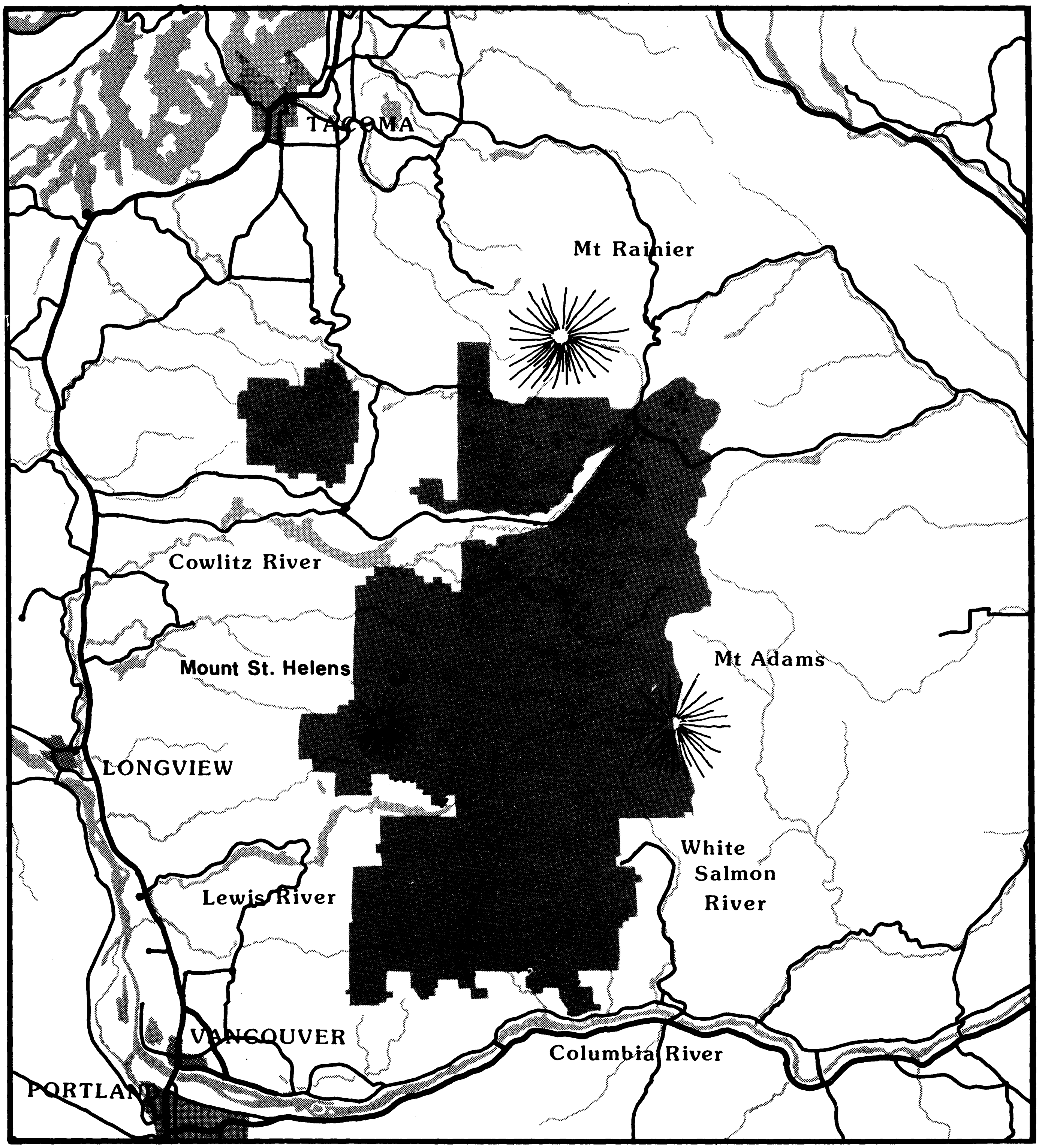

Figure 2. Western Hemlock Zone plot locations on the Gifford Pinchot National Forest

Uses of Plant Associations in Forest Management

The underlying value of plant association guides is that, because plant associations are indicators of their environment, they allow one to make inferences about a wide range of ecosystem factors (i.e., moisture, temperature, soil and hydrologic condition, wildlife, etc.). The association concept helps reduce complex vegetation patterns to an understandable and managable set of types. This helps users to more easily "read" the landscape, and communicate that information to others in an organized fashion.

This association classification should be widely used on the Forest. Engineers can use plant associations to locate high water table areas. Recreation planners can locate campsites in plant associations that quickly recover from trampling and resist soil compaction. Silviculturists can use them to help decide where shelterwood harvest rather than clearcutting will produce the best results, where severe brush competition may follow broadcast burning, or where cold-tolerant species should be used in reforestation. Plant associations differ in their ability to provide forage and hiding cover for wildlife, an important consideration in managing big game. Some associations may be particularly prone to development of damage through disease or windthrow. Fuels managers can infer site moisture gradients useful to area fuel management plans.

At a broader level, plant associations provide a framework for storing and retrieving data on response of different kinds of sites to different forms of management, and for applying research results or recommendations to actual land areas. As our knowledge about plant associations increases, their value as tools for management will increase as well. The patterns of associations we see in nature are the result of the year-in and year-out struggle of plants with their environment, responding to far more physical and biological variables than we could ever hope to accurately measure. And it is just this resource (the vegetation) that we, as land managers, are largely interested in, both for its own merits and its enormous effects on most other valued attributes of a National Forest.

CHAPTER 2 THE WESTERN HEMLOCK ZONE

OVERVIEW OF THE ASSOCIATIONS

The dominant environmental features which affect the distribution and appearance of plant associations in the western Cascades are effective moisture and temperature. Figure 3 displays an idealized interpretation of the distribution of the plant associations described in this guide along temperature and effective moisture axes. Temperature is largely a function of elevation, but topographic position relative to cold air drainages can also be important. Effective moisture measures the relative amount of soil water available to plants. This is just as much a function of soil water holding and sub-irrigation processes as it is a function of incident precipitation. Physiographic features of Western Hemlock Zone associations on the Gifford Pinchot National Forest are summarized in Table 2.

Wet-site Plant Associations

The wettest areas in the Western Hemlock Zone include forested wetlands characterized by skunk cabbage (TSHE/LYAM). The other very moist forested associations are Western hemlock/Ladyfern (TSHE/ATFI) and Western hemlock/devil's club/swordfern (TSHE/OPHO/POMU). The former occupies very moist and shaded lower slopes and bottomlands whereas the latter includes a variety of very moist forests from riparian to near-riparian to excessively wet areas prevalent on the western slopes of the Randle Ranger District.

Moist-site Plant Associations

Four associations indicate moist (not wet) conditions. Two are characterized by the presence of Oregon oxalis: Western hemlock/ swordfern- Oregon oxalis (TSHE/POMU-OXOR) (at warm sites in the western portions of Wind River and Randle RD's and St. Helens N.V.M.), and Western hemlock/ Alaska huckleberry/ Oregon oxalis (TSHE/VAAL/OXOR)(rare, restricted to the western tip of the G.P.). The other two moist-site associations are more widespread: Western Hemock/swordfern (TSHE/POMU) and Western hemlock/ foamflower (TSHE/TITR). These have a rich herbaceous flora and high timber productive potential, though moist soils can limit management activities.

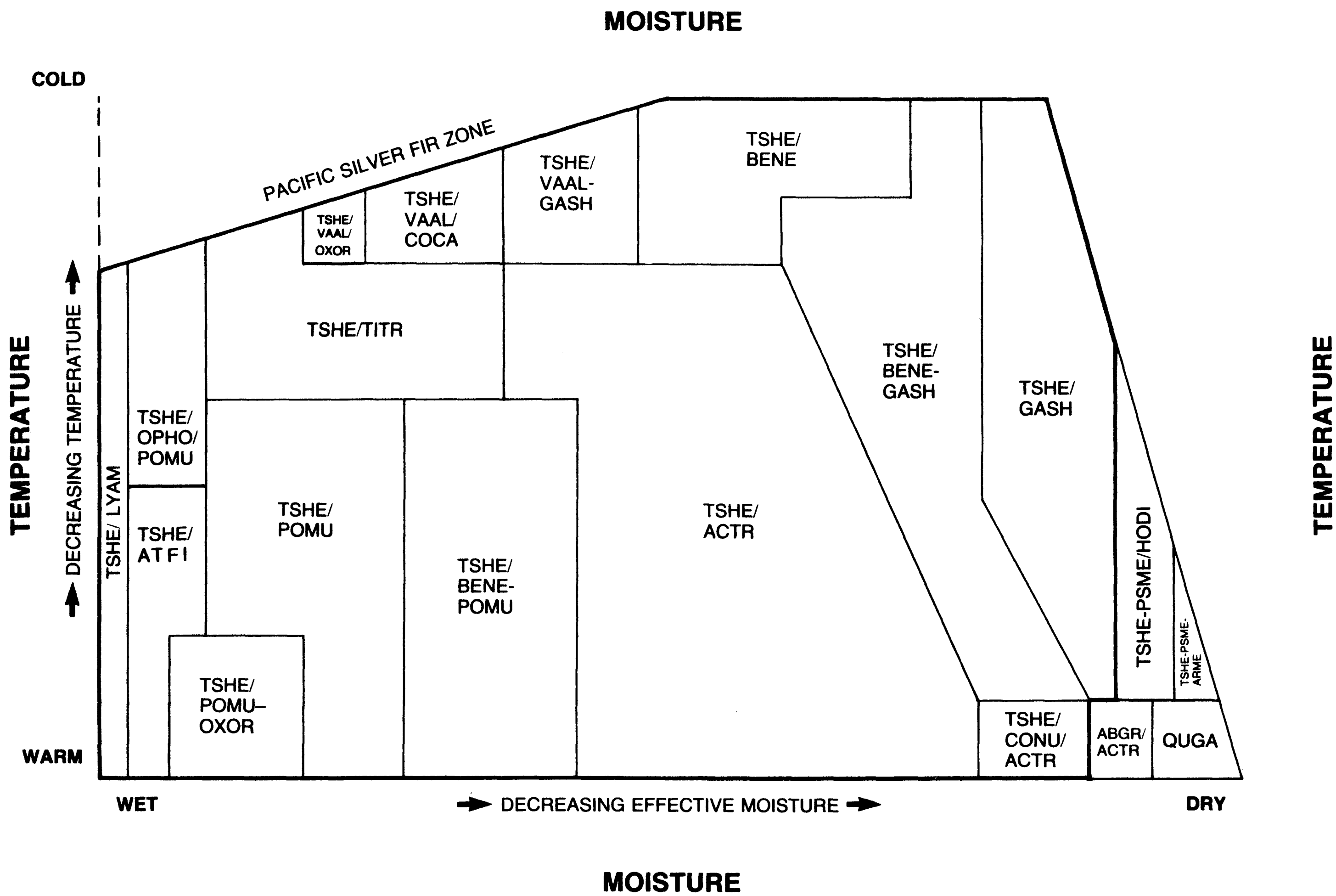

Figure 3. Idealized environmental relationships of the plant associations of the Gifford Pinchot National Forest Western Hemlock Zone. Abbreviations are described in Table 1. The grand fir (ABGR) and oak (QUGA) types will be described in future publications.

Table 2. Mean elevation and slope, and percent of study plots on the Gifford Pinchot National Forest of each Western Hemlock Zone association by elevation, slope, aspect and topographic microposition classes.

Association:	TSHE/ LYAM	TSHE/ ATFI	TSHE/ OPHO/ POMU	TSHE/ VAAL/ OXOR	TSHE/ POMU- OXOR	TSHE/ TITR	TSHE/ POMU	TSHE/ BENE/ POMU
Elevation (ft.)								
Mean	2200	1785	1876	1830	1606	1788	1639	1794
% < 1500		38	24		43	37	50	25
% 1500-1999		13	47	50	43	31	25	44
% 2000-2499	100	50	24	50	14	23	13	19
% 2500-2999							13	13
% > 3000			6			8		
Slope (%)								
Mean	0	34	32	40	33	27	40	39
% 0-15%	100	25	35		21	44	13	13
% 16-30%		13	18	50	29	19	31	13
% > 30%		63	47	50	50	37	56	75
Aspect								
% North (316°-45°		50	35	50	50	15	25	38
% East (46°-135°)		13	12		7	22	25	25
% South(136°-225°)		38	29		7	41	31	19
% West (226°-315°)	100		24	50	36	22	19	19
Topographic Microposition								
% Ridgetops			6					6
% Slope upper 1/3			25				20	13
% Slope mid 1/3		14	38		43	26	40	38
% Slope lower 1/3		57	6	50	14	39	27	25
% Bench				50	7	22		6
% Toe of Slope			13		14	4		6
% Bottom	100	29	13		21	9	13	6

Association:	TSHE/ VAAL/ COCA	TSHE/ VAAL- GASH	TSHE/ ACTR	TSHE BENE	TSHE/ BENE- GASH	TSHE/ GASH	TSHE/ CONU/ ACTR	TSHE- PSME/ HODI	TSHE- PSME- ARME
Elevation (ft.)									
Mean	2347	2151	2024	2552	1996	2110	1934	2173	1940
% < 1500	15	13	22	3	21	25	20		
% 1500-1999	15	38	28	6	24	20	30	50	50
% 2000-2499	23	25	28	37	43	20	40	50	50
% 2500-2999	38	25	14	34	10	30	10		
% > 3000	8		9	20	2	5			
Slope (%)									
Mean	26	26	35	49	39	39	40	42	44
% 0-15%	38	38	28	9	17	19	20		
% 16-30%	31	38	22	6	21	14	10	13	
% > 30%	31	25	51	86	62	67	70	87	100
Aspect									
% North (316°-45°		13	26	26	19	43	20	13	
% East (46°-135°)	46	63	15	6	10	14	20	13	
% South(136°-225°	31	13	29	37	40	19	20	50	
% West (226°-315°	23	13	30	31	31	24	40	25	100
Topographic Microposition									
% Ridgetops		13	4		5	10			50
% Slope upper 1/3	8	13	18	15	24	15	50	63	50
% Slope mid 1/3	15	25	27	48	19	25	10		
% Slope lower 1/3	31	38	27	30	36	35	20	38	
% Bench	31		5	3	10	10	10		
% Toe of Slope	15		6		2		10		
% Bottom		13	12	3	5	10			

Intermediate (mesic) Plant Associations

The greatest area of the Western Hemlock Zone on the Gifford Pinchot National Forest has intermediate moisture availability, and is occupied by associations indicative of "mesic" (or moderate) conditions. These are quite productive and fairly robust with respect to harvest activities. The Western hemlock/dwarf Oregon grape/ swordfern type (TSHE/BENE/POMU) has abundant herbs and shrubs, but lower productivity than the similar, but more moist and herb-rich, TSHE/POMU association. The most widespread association in this zone is Western hemlock/ vanilla-leaf (TSHE/ACTR). This association is quite productive and its abundance is a substantial reason for the fame of the Gifford Pinchot National Forest as a timber producing area.

TSHE/BENE is characterized by an absence of herbs and a sparse shrub layer, except for the dwarf Oregon grape, and fairly low timber productivity for this zone. It may be an intergrade association to the Pacific silver fir series. TSHE/BENE-GASH is a very widespread type which indicates fairly dry conditions, typically occurring on upper slopes and in areas away from the very rainy western portion of the G.P. NF.

Two Alaska huckleberry associations complete the mesic portion of the environmental grid (see Figure 3): Western hemlock/Alaska huckleberry/dogwood bunchberry (TSHE/VAAL/COCA) and Western hemlock/Alaska huckleberry-salal (TSHE/VAAL-GASH). These associations are restricted to cool areas, either close to the Pacific silver fir zone or on benches where cold air may accumulate. They are somewhat less productive than most other Western Hemlock Zone plant associations.

Dry-site Plant Associations

The Western hemlock/Salal (TSHE/GASH) association is fairly common on the dry portions of the Packwood Ranger District, especially on steep slopes where shallow, coarse soils predominate. On rock outcrops near the Cowlitz valley, the presence of madrone indicates the the Western hemlock-Douglas-fir -madrone (TSHE-PSME-ARME) association. Western hemlock- Douglas-fir/ Oceanspray (TSHE-PSME/HODI) is a very dry association characterized by rocky soils, upper slope or ridge positions, and low precipitation. Near the Columbia River hot and dry sites may exhibit the Western hemlock/Dogwood/Vanilla-leaf (TSHE/CONU/ACTR) association. Though difficult to reforest, it has fairly deep soils and good timber productivity.

We have depicted Oregon white oak woodlands (QUGA) on the environmental grid (Figure 3) though they have not yet been sampled . These are very dry and grassy areas on steep, south-facing slopes, primarily near the Columbia River. Some big reforestation headaches have been created in the past by the inclusion of these oak woodlands within harvest units, because they are so extremely dry. These areas should be avoided when designing timber sales and left to preserve their high wildlife and scenic values. The Bear Creek area of the Wind River Ranger District also includes small areas of the dry Grand Fir Zone within the context of the Western Hemlock Zone.

THE IMPORTANCE OF FIRE

Plant communities across the Forest are greatly affected by the vast forest fires which have burned substantial areas, especially during the early part of this century. Historically known large wildfires have usually resulted from strong east winds following periods of summer drought (Hogfoss 1985). In 1902, 480,000 acres on and near the Gifford Pinchot National Forest burned. Half was the Yacoult Burn, but other major fires included the Lewis River Burn (30,000 acres), Siouxon Fire (30,000+ acres) and the Cispus Burn (50,000 acres)(Hogfoss 1985). Other large fires occurred this century including reburns in the Yacoult and Cispus Burns. Similar large-scale fires no doubt occurred in the past and have been of primary importance in creating opportunities for extensive Douglas-fir forests to become established.

This plant association classification works where the dominant forest is about 50 years or older. Careful observation of regeneration tree species is important in these areas to properly determine the corect series: whether it be western hemlock, grand fir, Pacific silver fir or mountain hemlock.

CLIMATE

The Western Hemlock Zone includes the lower elevation, moist forests of the Western Cascade portion of the Gifford Pinchot National Forest. Precipitation falls primarily as rain although snow occurs throughout the zone. Yearly totals range from about 60 inches near the Columbia River and by Packwood, to over 110 inches on the west slopes of the Forest. Precipitation is greatest on the southwest sides of Mt. St. Helens and Mt. Rainier. The upper elevation boundary of the Western Hemlock Zone occurs where long-term snow-packs become the rule. A snow transition zone seems to exist between 3000-3500 feet in elevation, where snowpacks can be eliminated by warm rainfall events at any time during winter. The boundary between the Pacific Silver Fir Zone and the Western Hemlock Zone varies in elevation from about 3000 feet to as low as 2500 feet near Mt. Rainier. Only a few warm and moist sites east of the Cascades crest on the Mt. Adams Ranger District are classified as being in the Western Hemlock Zone.

The great productivity of these forest-lands is due to the abundant moisture as well as the moderate temperature regime. Particularly at lower elevations, trees actively photosynthesize most of the year (Lassoie 1982), so biochemical growth occurs for much greater periods than merely the time of shoot elongation. It is likely that at low elevations half of the total photosynthate in Douglas-fir is produced between October and May. Summer drought is the rule in the Western Cascades. This accentuates the importance of the water-holding and supplying capacity of soils.

Rainfall patterns across the Forest are only generally understood. Figure 4 depicts rainfall predicted by U.S. Weather Bureau models. This figure is a general guide, but vegetation seems to be a much better way of understanding site-specific moisture status. The rainfall map apears to be most inacurrate in its depiction of equal rainfall for the west slopes of the Forest and the low elevation eastern portions of the Cowlitz valley.

The primary factors influencing climate are latitude, topography and continental versus marine influence (Johnson and Dart 1982). In general, there is a tendency for rainfall to increase with latitude, and for the rainy season to begin earlier in the year to the north. To the south summers are drier and there is more variability in precipitation from year to year. The eastern portion of the Western Hemlock Zone still has predominantly oceanic climatic influences, but there is a slight tendency towards continental characteristics: colder and drier.

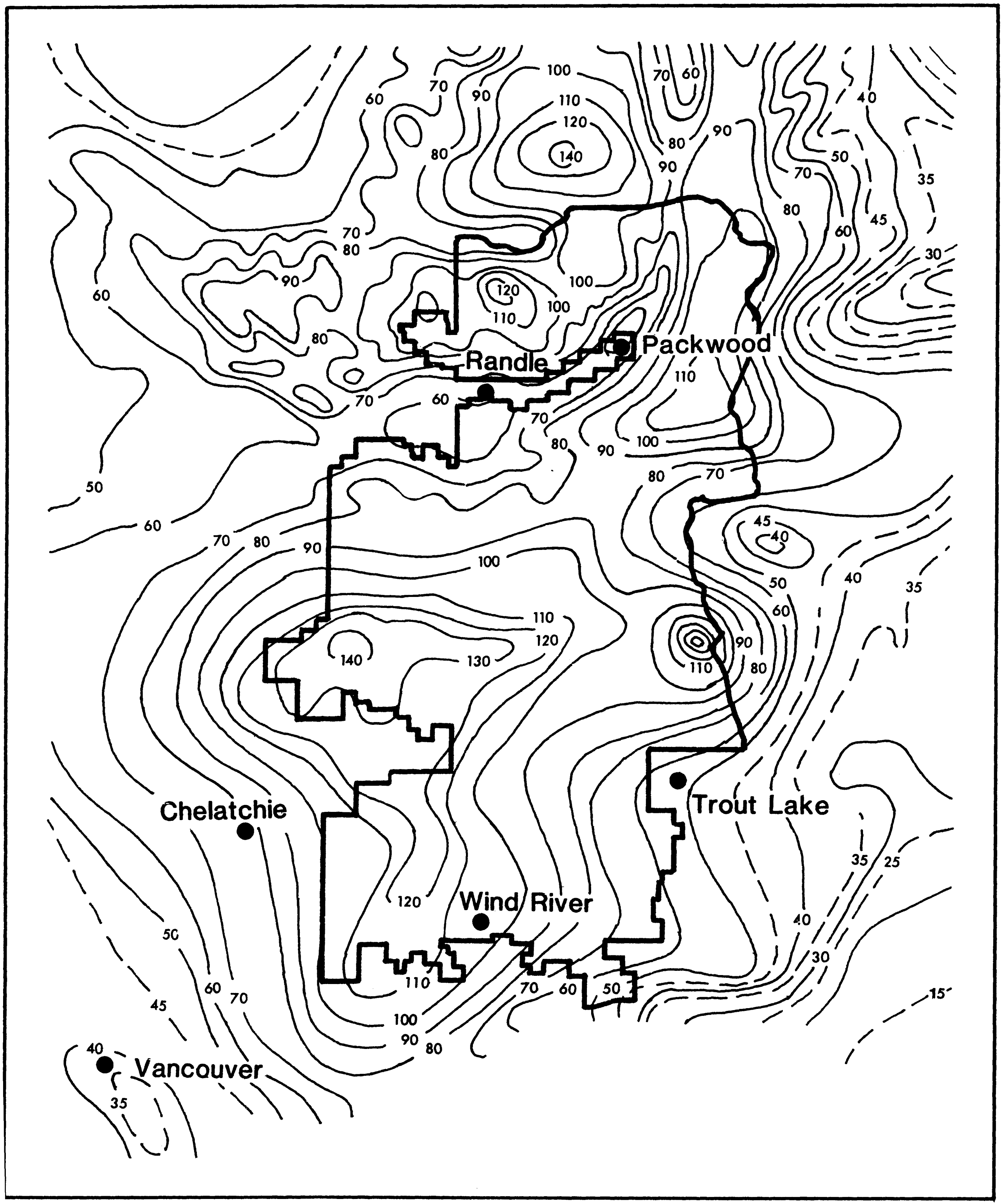

Figure 4. Annual precipitation for the Gifford Pinchot National Forest (U.S. Weather Bureau 1965)

Highly dissected topography is typical of the Western Hemlock Zone. Numerous major ridges have substantial effects on local precipitation. Heavy rain results from moisture laden marine air masses moving inland from the southwest. As storms hit the Western Cascades, the air rises and cools, producing rain. The west slopes of the Gifford Pinchot National Forest are thus extremely moist. As storms pass towards the northeast, they repeatedly must rise over the major north-south ridges, creating a slight rain-shadow effect which increases to the east. This is illustrated on the Randle Ranger District where the Western Hemlock Zone gradually becomes drier with eastward movement. The lower slopes of Vanson Peak on the western edge of the Forest are extremely moist. Major ridges separate Quartz, Iron, Yellowjacket, and McCoy Creeks and the Cispus River, which causes a gradual trend to drier, slightly continental climates for the latter drainages.

The Cowlitz Valley has a unique rainfall pattern because it is a low elevation penetration into the central Cascades and because it is surrounded by such high ridges. Rainfall decreases substantially moving east from Glenoma, even though elevation changes little. By the time storms get past Packwood to the Ohanapecosh area they have lost much of their moisture. Yet, as air masses rise and cool on the slopes above Packwood, precipitation increases significantly above the Western Hemlock Zone.

The area south of Mt. Rainier exhibits a similar pattern but on a grander scale. There are few mountains to the west to intercept incoming moisture. This, coupled with the massive size of Mt. Rainier itself, creates the potential for extremely high rainfall amounts. The greatest total snowfall ever recorded in the United States, 1122 inches (water year 1972), was at Paradise on the southwestern flank (elev. 5247 ft.) of Mt. Rainier. The portion of the Gifford Pinchot NF near Mt. Rainier has a much colder general climate than elsewhere on the Forest. The upper boundary of the Western Hemlock Zone is as low as 2500 feet in this area. Lower elevations are very moist west of Mt. Rainier, becoming gradually drier to the east in the Ohanapecosh drainage. Soil and air temperatures for two Western Hemlock Zone habitats in Mt. Rainier National Park are summarized by Greene and Klopsch (1985).

Mt. St. Helens is another major feature which channels incoming storms, thereby affecting the local climate. Storms are deflected up the Lewis River, causing the moister environments to extend farther east than elsewhere on the

Forest. Mt. St. Helens also affects the region to its northeast by intercepting some moisture which otherwise would fall there.

The effective moisture concept integrates the factors which affect water availability for plant growth and evaporative demand. Though incident moisture varies by a factor of 2-2.5 within the Forest, effective moisture is much more variable, and is affected by very local soil, topographic and micro-site characteristics. Bedrock fracture, slope, soil depth, stoniness, texture, structure and organic matter content can all affect soil water infiltration, holding capacity and releasing capacity. For instance, stony soils with abundant sand have little moisture-holding capacity and so are occupied by dry-site plant associations. Volcanic ash, though coarse textured, has a fairly good moisture holding ability. Sub-irrigation may confound the observed plant-to-soil property relationships. Such confounded situations are very widespread in this region because of the steep mountainous terrain and the various glacial, volcanic and colluvial processes which dominate soil formation.

When we discuss wet- or dry-site plant associations, we are referring to the effective moisture of the site which affects vegetation. Plant associations can serve as very useful tools to estimate climate, when properly calibrated and interpreted.

GEOLOGY

The geologic materials of the Gifford Pinchot National Forest are dominated by volcanics, with sedimentary and metamorphic rocks occurring only in isolated areas. Five aspects of local geology help understand the patterns of vegetation we see on the landscape: (1) material type; (2) age; (3) tectonic displacement and deformation; (4) glaciation; (5) recent geomorphological processes. This discussion is based on the geologic map by Hammond (1980) and papers by Walker and Griggs (1979), Swanson (1979) and Franklin and Dyrness (1973) and the conceptual framework of Jenny (1980).

Types of Parent Materials

An important dichotomy in types of volcanic geological materials is between hard, fine to medium grained igneous rocks such as basalts, andesites and dacites, and softer, volcanic pyroclastics such as breccias and tuffs. Throughout the last 50 million years this region has experienced numerous volcanic episodes which have resulted in vast deposits of extrusive, hard lava rocks of basalt and andesite. These layers are usually interbeded with tuffs and breccias resulting from pyroclastic flows and consolidated tephra deposits. There are also numerous hard rock intrusions (dikes and plutons). The lavas and intrusive rocks are all resistant to weathering and result in major ridges and relatively shallow, stony soils. Some breccias are also quite hard and function like andesites and basalts. Most tuffs and breccias are easily weathered and if not eroded, form deep soils able to hold considerable moisture. They also may lead to landflows because they are non-cohesive and are heavy and slippery when saturated.

Whether igneous or pyroclastic, the chemical composition of the material is also important. The more basic rocks (basalts, andesites and their associated pyroclastics) have higher calcium, magnesium, and phosphorus contents than is typically found in acidic igneous rocks like rhyolite or granite. The prevalence of the basic volcanics on the G. P. is partially responsible for the high productivity of this area.

Most of the Forest north of the Lewis River has also been affected by the very recent deposits of pumice and ash from Mt. St. Helens and Mt. Rainier. These materials are porous and have moderate moisture holding capacity. However, they are easily penetrated by roots. The multiple pumice layers often include semi-impermeable layers where soil water accumulates and is readily available for plant use. In the very high rainfall areas on the western part of the Forest these drainage and soil aeration properties may aid plant growth. In the drier, eastern part of the Forest this material is not a particularly good growth medium unless it is mixed into the soil by colluvial processes.

The Mineral Block in the Randle Ranger District is geologically distinct. It is affiliated with the Puget Trough geological province. It is here as well as in parts of the Cowlitz Valley that sedimentary rocks may be found.

Age of Parent Materials

The volcanic materials can be categorized as either recent (less than 5 million years, defining the High Cascades Province), or old (5-50 million years, the Western Cascades Province). Very old materials (> 70 million years) are virtually absent from the Western Hemlock Zone and occupy only tiny isolated areas near White Pass elsewhere on the Gifford Pinchot National Forest. Age determines the extent of weathering which may have taken place and the cumulative impact of various tectonic and glaciation events. The older materials are more fractured and porous and, other things being equal, may support deeper soils with greater weathering and moisture-holding capacity.

Recent surficial deposits are common because of volcanism, occasional mass movement, and glacial deposits. Where recent volcanic, land flow or glacial deposits have not, due to their young age, formed suitable soils, special environments are found. Although within the greater geographic Western Hemlock Zone, they may not support western hemlock. Examples include the lower Kalama River lahar and the Big Lava Bed (Wise 1970) which are dominated by lodgepole pine.

Tectonic Processes

The predominant tectonic processes in the Western Hemlock Zone have been folding and faulting in the older Western Cascades province. The northwest/southeast ridges are the result of folding which occurred before the recent emergence of the huge volcanos which comprise the High Cascades province. These ridges cause changes in vegetation over short distances from west to east by interception of incoming moisture from east-bound marine storm systems. Faulting at various time periods has lead to additional complexity. The overall elevation which limits the Western Hemlock Zone has been greatly increased by a general uplifting of the Western Cascades which may have begun 20 million years ago.

The recent volcanism which formed the High Cascades and deposited abundant tephra in the Western Hemlock Zone is thought to be a result of plate tectonics. The Gorda deep-sea plate appears to be sliding beneath the North America continental plate with the resulting friction producing the "ring of fire" which includes our volcanos.

Glaciation

The Gifford Pinchot National Forest experienced only alpine glaciation during the ice ages, and the Western Hemlock Zone was only partially affected (Hammond 1980). Major glaciers extended down the Nisqually, Cowlitz, Cispus, Lewis and Wind Rivers. The northern valleys were decidedly more affected than the southern and western drainages. Glaciation lead to broad, U-shaped valleys with coarse glacial till as parent material. Below the extent of the glaciation, such as in the Cowlitz and Lewis basins, valleys are more V-shaped from typical fluvial processes. Glacial till is not widespread in the Western Hemlock Zone, but where found it results in relatively unproductive, young soils which show the effects of compaction by the heavy ice.

Recent Geomorphic Processes

Geomorphology acts as a critical link to understanding the affect of geological processes on the distribution and productivity of vegetation. Available rooting volume is key. The steep terrain common to the Western Hemlock Zone leads to extensive mixing of soils and parent materials through colluviation. Lower and mid slope positions in this zone frequently have a mixture of rock types from upslope. Colluvial mixing serves to bring fresh, unweathered rock up into the rooting zone which partially counteracts the constant downward movement of nutrients by leaching. Soil horizon development is greatly reduced by this soil churning, which is enhanced by uprooting of wind-thrown trees. Upper slopes and ridges usually have shallow, stony soils with poor nutritional and moisture holding properties.

Landslides and landflows are occasional events which add complexity to soils. Landslides have hummocky terrain and very rapid vegetation changes over short distances. A spotty distribution of wet-site plant associations is a hint that a landslide may exist and particular management strategies are required.

Relationship of Plant Associations to Parent Material

Within the Western Hemlock Zone, there appears to be only a general relation between the major types of geologic parent materials and plant associations. This may be partly due to the difficulty in determining true parent materials. However it is more likely that site moisture conditions are of overriding importance to the vegetation in this forest zone.

Table 3 presents a percentage breakdown of our plots within each association by parent material. Some of the evident pattern is more likely due to the geographical distribution of the parent materials rather than the direct affect of the geology on plant associations. For instance, 82% of the plots in the Western hemlock/ Swordfern-oxalis association (TSHE/POMU-OXOR) occur on igneous rocks and no plots were found on pyroclastics. This may be due to the prevalence of basalts and andesites on the western fringe of the Forest where the climatic conditions required by this association are found. Most of the plots in the Western hemlock/ dwarf Oregon grape association (TSHE/BENE) were on igneous materials. In this case the geology probably is meaningful because this association seems to require sites with more stony, shallow soils. Western hemlock/ foamflower (TSHE/TITR) and Western hemlock/ lady fern (TSHE/ATFI) were most commonly found on tephra. This reflects the dominance of this parent material in the northern portions of the G. P. Western Hemlock Zone where the extensive cool and moist environments which these associations favor are common.

SOILS

Soils are the basic resource upon which all vegetation depends for sustained production. At the extremes, soil properties create very obvious limits to the distribution and productive capacity of plants. The key soil ingredients which are required for plant growth are moisture, nutrients and oxygen. The latter is only limiting in areas of sustained high water tables such as may be found in Western hemlock/ skunk cabbage and Western hemlock/ devil's club/ swordfern associations. The moisture holding and releasing capacity of soils appears to be most important in determining the composition and distribution of plant associations in the Western Hemlock Zone. It is this relationship which makes knowledge of plant associations valuable to the land manager. Nutritional aspects of soil-plant association relationships are much more subtle, though general trends are noteworthy. Soil organic matter is the most critical single attribute which land managers can affect. Organic matter provides much of the soil nutrition through nutrient cycling processes as well as valuable moisture holding capacity. In addition, organic matter fosters the growth of mycorrhizae which are required for conifer growth.

Table 3. Per Cent of plots in each association on the Gifford Pinchot National Forest Western Hemlock Zone having particular geologic parent materials.

Association	Basalts & Andesites	Breccias & Tuffs	Tephra	Mixed
TSHE/LYAM	100			
TSHE/ATFI	43		57	
TSHE/OPHO/POMU	69		31	
TSHE/VAAL/OXOR			100	
TSHE/POMU-OXOR	82		18	
TSHE/TITR	25	17	58	
TSHE/POMU	47	7	33	13
TSHE/BENE/POMU	43	29	29	
TSHE/VAAL/COCA	70	20	10	
TSHE/VAAL-GASH	63	13	13	13
TSHE/ACTR	46	21	28	5
TSHE/BENE	82	7	11	
TSHE/BENE-GASH	54	24	19	3
TSHE/GASH	63	11	26	
TSHE/CONU/ACTR	44	44	11	
TSHE-PSME/HODI	43	57		
TSHE-PSME-ARME	100			
OVERALL TOTAL %	53	19	26	3

Table 4. Forest floor and soil depth of Gifford Pinchot National Forest Western Hemlock Zone plots by plant association. The forest floor is divided into L (fresh litter), F (fragmentation layer) and H (humus layer). Total soil depth is the depth to bedrock or crumbling regolith up to 100 cm maximum. Rooting depth is the depth of soil penetrated by 90% of the roots. Effective soil depth is the total soil depth discounted by the per cent coarse soil fragments (> 2mm) throughout the profile. A horizon thickness is pedogenetically defined and is virtually always an "A1" type.

	FOREST FLOOR THICKNESS IN MM				SOIL DEPTH IN CM				
ASSOCIATION	L	F	H	TOTAL	TOTAL SOIL DEPTH	ROOTING DEPTH	EFFECTIVE SOIL DEPTH	A HORZ THICK	# SOIL PITS
TSHE/LYAM									
MEAN	25	25	0	50	65	37	7.5	48	1
TSHE/ATFI									
MEAN	15	29	0	44	100	85	30	51	7
STDEV	7	24	0	28	0	13	13	48	
TSHE/OPHO/POMU									
MEAN	15	57	3	74	98	84	34	20	16
STDEV	7	33	6	34	6	13	14	9	
TSHE/POMU-OXOR									
MEAN	19	33	4	56	95	76	38	28	13
STDEV	12	30	3	37	18	18	20	29	
TSHE/VAAL/OXOR									
MEAN	20	40	10	70	100	75	40	26	1
TSHE/TITR									
MEAN	15	22	10	47	100	84	32	23	25
STDEV	7	19	18	32	0	13	13	13	
TSHE/POMU									
MEAN	13	31	4	47	100	86	29	46	16
STDEV	6	24	8	27	.5	14	16	49	
TSHE/BENE/POMU									
MEAN	13	34	5	52	94	90	40	36	14
STDEV	6	23	5	27	15	17	22	26	
TSHE/VAAL/COCA									
MEAN	13	47	8	68	99	86	28	27	11
STDEV	7	29	9	34	2	15	14	20	

Table 4 continued.

ASSOCIATION	FOREST FLOOR THICKNESS IN MM L	F	H	TOTAL	SOIL DEPTH IN CM TOTAL SOIL DEPTH	ROOTING DEPTH	EFFECTIVE SOIL DEPTH	A HORZ THICK	# SOIL PITS
TSHE/VAAL-GASH									
MEAN	13	31	8	52	82	68	32	29	8
STDEV	3	25	5	28	24	20	18	20	
TSHE/ACTR									
MEAN	16	31	4	51	95	84	28	25	87
STDEV	9	24	12	28	11	15	16	19	
TSHE/BENE									
MEAN	15	41	0	55	96	89	27	23	28
STDEV	5	30	0	31	17	19	14	35	
TSHE/BENE-GASH									
MEAN	14	32	.5	46	96	85	29	33	37
STDEV	6	18	2	20	13	16	17	36	
TSHE/GASH									
MEAN	15	27	0	42	97	84	30	25	19
STDEV	6	17	0	20	9	16	18	27	
TSHE/CONU/ACTR									
MEAN	10	21	4	35	99	89	53	47	9
STDEV	6	9	6	15	2	13	23	24	
TSHE-PSME/HODI									
MEAN	10	16	4	30	67	57	19	33	7
STDEV	5	13	10	15	28	18	10	17	
TSHE-PSME-ARME									
MEAN	13	5	0	18	90	84	19	70	2
STDEV	4	7	0	3	13	22	7	90	

Classification of Western Hemlock Zone Soils

Most of this zone includes relatively young and undifferentiated soils which are clasified as Inceptisols, either Umbrepts (having dark surface horizons), Ochrepts (having pale brown upper horizons) or Andepts (dark soils of volcanic ash) (Dawson et al. 1972). These soils are generally well drained and are dominated by silty to sandy-loam textures with little clay accumulation. Soils on the softer and older parent materials may exhibit more horizonal development and appear as Ultisols or Alfisols. Spodosols (soils having pale, leached A2 horizons) are virtually absent from the Western Hemlock Zone, though the podsolization process of downward migration of iron and clays occurs. The soil classification reflects the moderate temperature regimes and generally moist conditions found in this zone compared with higher elevation forest zones or coniferous forests elsewhere in the world.

Relationship of Plant Associations to Soil Depth

The volume of soil material capable of holding moisture depends on particle size and type, pore space and soil structure. Soil organic matter and clay size particles hold the most water, though clay soils can be inefficient at releasing moisture to roots. Gravels and stones reduce the rooting volume of soils. Table 4 presents four measures of soil depth by plant association. The total soil depth variable is meaningful where it is less than the 100 cm maximum depth of our soil pits. Most areas in the Western Hemlock Zone have soils this deep, but shallower depths indicate particularly poor potential for forest productivity. Associations with such shallow soils are Western hemlock- Douglas-fir/ oceanspray (TSHE-PSME/HODI), Western hemlock/ Alaska huckleberry/ salal (TSHE/VAAL-GASH), and Western Hemlock/ skunk cabbage (TSHE/LYAM). The former types have rocky soils and the latter exists in standing water. Rooting depth is the depth penetrated by 90% of the roots. The associations have a similar pattern as for total soil depth. Noteworthy is the fact that rooting depth is at most 90 cm. This points out that the upper portion of the soil is critical for vegetation and for sustained productivity. The upper soil is most easily damaged by erosion, skidding, and compaction by heavy machinery.

The effective soil depth variable (Table 4) is a simple index of the total soil volume useable by roots. It is calculated by discounting each soil layer described in the field by an estimate of its coarse fragment (particles >

2mm) content. Thus, a deep, stony soil may have a smaller effective soil depth than a more shallow soil which lacks coarse fragments. Plant associations with the rockiest soils and the poorest moisture regimes for plant growth are Western hemlock- Douglas-fir/ oceanspray (TSHE-PSME/HODI) and Western hemlock- Douglas-fir- madrone (TSHE-PSME-ARME). Other associations with lower values for effective rooting depth have moderately rocky, but excessively drained soils, and frequently occupy upper and mid-slope positions. These dry to mesic associations include: Western hemlock/ dwarf Oregon grape (TSHE/BENE), Western hemlock/ dwarf Oregon grape-salal (TSHE/BENE-GASH), Western hemlock/ vanillaleaf (TSHE/ACTR) and Western hemlock/ salal (TSHE/GASH). Some associations with moist environments also may have fairly small effective soil depths due to high water tables. These associations occupy sites with either high incident precipitation or sub-surface drainage. Western hemlock/ ladyfern (TSHE/ATFI), Western hemlock/ swordfern (TSHE/POMU), and Western hemlock/ Alaska huckleberry (TSHE/VAAL/COCA) fit this category. Pumice dominated soils may be comprised mainly of large soil particles but are not necessarily unfavorable to plant growth, since the porous pumice retains a significant amount of plant-available moisture.

THE FOREST FLOOR

The forest floor is the surface organic material containing less than 50% mineral constituents. It is important to the forest because it is the most active site of nutrient cycling processes and it serves important insulative and anti-erosion functions. Much of the soil organic matter passes through the forest floor and it can be the site of considerable rooting. The appearance of the forest floor can tell a lot about functional processes of nutrient cycling. The forest floor is also the most sensitive part of the soil system. Removal by fire, machinery or erosion is unfavorable to long term sustained forest productivity, especially where it comprises a large portion of the soil's organic matter.

The great dichotomy of forest floor types found in coniferous forests is between mor and mull. The difference is the extent to which surface organic matter is fragmented and mixed into the mineral soil. Mor forest floor types have little mixing. They are characterized by sometimes massive surface organic accumulations sitting on top of mineral soil. These layers are susceptible to loss from fire. Mull forest floors have significant mixing of organic material into the mineral soil where it is readily available to roots and soil organisms for nutrition and water holding functions. Mulls generally have thinner surface organic accumulations than do mor forest floors. Between this mor-mull dichotomy exists a gradient of forest floor types with the intermediate types called moders (or duff mulls).

For convenience we usually divide the forest floor into 3 sublayers, L, F, and H. These have different functional roles as well as different physical appearances. L layers include the fairly fresh and unconsolidated needles and twigs on the surface. F layers are the site of initial fragmentation and may be the site of intense soil animal activity. H layers are organic layers in which the original plant parts are not discernible without magnification. H layers are absent when organic matter is rapidly mixed into the mineral soil, yet when present, they are important substrates for roots. The thicknesses of these layers on our study plots are presented by association in Table 4.

Classification of Forest Floors

We have utilized the British Columbia Province system of humus form classification to further categorize the appearance of forest floors in the Western Hemlock Zone (Klinka et al. 1981). Table 5 presents seven groups found on the Gifford Pinchot National Forest plots. The only mor type found is a hemimor. It has a pronounced H layer, but the H layer is smaller than the L+F layers. Moder forest floor types are prevalent in the Western Hemlock Zone. They usually include an H layer, but it is relatively thin and is accompanied by substantial mixing of organic material into the upper mineral soil. Four groups of moders were included in our samples. Velomoders are unusual; they have massive L layers and are typical in densely stocked young stands. The other three groups comprise a gradient from mor-like to mull-like conditions. Mormoders have substantial, fungal dominated H layers. Leptomoders display prominant H layers with some soil animal activity. Mullmoders have thin H layers and extensive mixing of organic matter into the mineral soil. Mull types indicate rapid decomposition and nutrient cycling; they lack H layers. The two groups are rhizomulls, which are dominated by roots, and vermimulls, which are dominated by earthworms and soil animals.

Relationship of Plant Associations to Forest Floors

The appearance and mass of the forest floor reflects a balance between the input of organic matter (litter production) and its decomposition. Decomposition rates are determined by temperature, moisture and the quality of the litter. Higher elevation forest zones (Pacific silver fir and mountain hemlock) are dominated by moder and mor forest floors and management must be especially careful of this resource in those areas (Brockway et al. 1983). Within the Western Hemlock Zone there exist much smaller extremes than in the Forest as a whole. Mull forest floor types are most common in the warmer associations where decomposition is rapid and snow accumulations are probably sporadic. These associations include Western hemlock/ dogwood/ vanillaleaf (TSHE/CONU/ACTR), Western hemlock-Douglas-fir/ oceanspray (TSHE-PSME/HODI), and Western hemlock/ swordfern (TSHE/POMU) (Table 5). The higher elevation and cooler associations tend to have thicker forest floors tending to the mor side of the moder category. Managers should attempt to conserve the forest floor in these associations: Western hemlock/ dwarf Oregon grape (TSHE/BENE), Western hemlock/ Alaska huckleberry/ dogwood bunchberry (TSHE/VAAL/COCA), Western hemlock/ Alaska huckleberry-salal (TSHE/VAAL-GASH), and Western hemlock/ foamflower (TSHE/TITR).

Table 5. Percent of plots on Gifford Pinchot National Forest within each association exhibiting particular forest floor forms. The form groupings are defined in the text.

	MOR TYPE	MODER TYPES				MULL TYPES	
ASSOCIATION	HEMIMOR	VELOMODER	MORMODER	LEPTOMODER	MULLMODER	RHIZOMULL	VERMIMULL
TSHE/LYAM					100		
TSHE/ATFI				20	60		20
TSHE/OPHO/POMU				46	46		8
TSHE/VAAL/OXOR					100		
TSHE/POMU-OXOR	9		18	36	27		9
TSHE/TITR			7	53	20		20
TSHE/POMU			8	17	33	25	17
TSHE/BENE/POMU	8			8	33	17	33
TSHE/VAAL/COCA			20	20	60		
TSHE/VAAL-GASH			29		57		14
TSHE/ACTR	1	1	8	31	25	7	25
TSHE/BENE				65	35		
TSHE/BENE-GASH			11	46	14	14	14
TSHE/GASH				27	60	7	7
TSHE/CONU/ACTR					50	13	38
TSHE-PSME/HODI		17		17			66
TSHE-PSME-ARME					100		
OVERALL TOTAL	1	1	7	33	33	7	18

SNAGS AND FALLEN TREES

Natural forests include a large amount of dead wood. Dead wood is a very important part of forest ecosystems which only recently is beginning to be appreciated for its many varied roles. These roles include providing a tremendous variety of habitat for wildlife and plants, and important functions relating to fire danger, nutrient cycling, and stream and landscape shaping processes (Harmon et al. 1986). Standing dead trees (snags) provide essential habitat for many bird species which nest in tree cavities (Neitro et al. 1985). Down woody debris can provide special habitats and safe sites for a vast array of animals (Maser and Trappe 1984). Down logs may persist for centuries as huge boles which slowly decompose into large spongy masses and have a variety of habitats favorable to microbes and plant roots. Snags and down wood have long been recognized for their functions as forest fuels which enhance wildfire spread. Streams and rivers in forested areas owe their pool and riffle structure largely to gravel beds shaped by logs from neighboring stands. Upland slopes may be churned by the root wads of fallen trees. Soil creep and surface erosion may be slowed by logs lying across steep slopes. Regeneration of clear-cuts may be aided by the shade provided to small seedlings by down woody debris. Clearly, these and other functions of dead wood are complex and interrelated.

Land managers have recognized the importance of snags and down logs. The proposed standards and guidelines for forest management call for maintaining some of this material in harvested areas and areas where vegetative manipulation occurs (Gifford Pinchot National Forest 1986). Protected snags would number two per acre and be evenly distributed. Large trees (> 40 feet tall and >21 inch DBH) of slowly decomposing species, such as Douglas-fir, larch or ponderosa pine are preferred. The proposal also calls for the protection of at least 3 down logs per acre which are preferably at least 21 inches in diameter and 16 feet long.

Currently there are relatively few data available concerning the abundance of snags and down woody material in natural forests. Our sampling included an assessment of snag abundance and condition, as well as measurements of down logs and fine fuels. Our data provide a useful baseline determination of conditions occurring in unmanaged stands of a variety of ages and species composition. An overview of this information is provided below.

The amount and type of snags and down logs in a forest is a product of a variety of stand history factors. Because of the long period required for the decomposition of large logs, this material may outlast the live trees in the forest. This carry-over from stand to stand is an important feature of larger logs which provide special habitats. The site characteristics which influence productivity and plant association composition may not be the dominant factors affecting the presence or condition of snags and down logs. We do not expect that knowledge of a site's plant association should be sufficient information to predict snag or down wood abundance. In the Western Hemlock Zone, fire history, disease patterns and tree species composition are more likely to determine patterns of dead wood distribution.

Several recent publications discuss in detail the role of snags and down woody debris in forests of the Pacific Northwest. The west-side wildlife habitat book includes very useful discussions of management for snags (Neitro et al. 1985) and down, dead wood (Bartels et al. 1985). Maser and Trappe (1984) published a delightful summary of the special world inhabiting down logs. Old-growth Douglas-fir forests are partially characterized by their special components of large down logs and snags (Franklin et al. 1981). The technical attributes and scientific literature regarding down woody debris have recently been reviewed in great detail by Harmon et al. (1986).

Snags

In the Western Cascades of Washington and Oregon there are at least 100 animal species which use snags and at least 53 species which depend on tree cavities for critical habitat (Neitro et al. 1985). At least 34 bird and one mammal species depend on snags for essential habitat on the Gifford Pinchot National Forest. Snags are also important as resting and feeding areas and provide structural heterogeneity to the forest canopy. The particular characteristics of snags depends on their species, decomposition status and size. The exact sequence which an individual snag follows depends a great deal on the agents causing its death and the animal excavations within the wood. Snag deterioration has been usefully summarized with a five-stage condition classification going from recently dead trees (condition 1) to thoroughly rotted standing snags (condition 5) (Cline et al. 1980).

Our sample plots included tallies of snags. Our plots are normally in undisturbed stands where snag tallies should be close to representing the natural, unmanaged forest condition. Species, diameter at breast height (DBH), height class (10-30 ft., 30-50 ft. and >50 ft.), cavity presence and deterioration condition class were recorded for each snag tallied (Wind River RD plots lacked height or condition classes). Minimum tally size was 10 inch DBH and 10 feet tall. We used condition classes similar to those of Cline et al. (1980); these are also utilized in the Western Washington and Oregon wildlife habitat management book (Neitro et al. 1985):

Snag Condition Classes

Condition 1 - Fine branches and bark intact.
Condition 2 - A few larger limbs present, bark present
Condition 3 - Limb stubs may be present, bark only partly intact.
Condition 4 - Bark nearly gone; solid buckskin.
Condition 5 - Rotted, soft and crumbly

Table 6 separates the number of snags per acre by the seral stage of the site, either early (< 100 yrs), mid (100-200) or late (> 200 yrs). In general, there are many snags in unmanaged stands, averaging 46 per acre for all plots in the Western Hemlock Zone. Tall snags are most important for wildlife use; their abundance was relatively constant across the stand age gradient, though in the late seral stands, the tall snags represent a greater proportion of the total. The late seral stage had a greater proportion of snags in the more rotted conditions and these snags were larger and contained more cavities. The total number of snags per acre was lowest in the late seral stands. This is likely due to the demise of smaller snags (suppression mortality) abundant in the earlier seral stages. Our values for cavities per acre should only be considered a rough index of actual values because of our difficulty in accurately assessing cavities at ground level. Nevertheless, there were more cavities found in the older forests. Most of the cavities in the younger forests were in carry-over snags from earlier stands. These snags are predominantly short and provide fewer perching or feeding opportunities for birds.

Plant associations do not appear to be very good predictors of snag abundance or characteristics. There are too many specific stand history factors which affect the supply of snags and their ability to persist over time. Table 7 summarizes the snag data by association. These values demonstrate the overall variability of snag occurrence. These data should not be used to predict snag densities. It is noteworthy that the more moist associations have generally larger diameter snags.

Table 6. Average weight and number of snags[1] and fallen trees by seral stage, Western Hemlock Zone, Gifford Pinchot National Forest.

	Total		Early Seral (30-100 yrs)		Mid-Seral (100-200 yrs)		Late Seral (> 200 yrs)	
	tons/ac	#/ac	tons/ac	#/ac	tons/ac	#/ac	tons/ac	#/ac
				SNAGS				
Condition 1[2]		5		7		3		4
2		18		18		25		8
3		9		8		12		6
4		6		6		5		7
5		8		8		7		9
Height 10-30'		20		24		26		17
30-50'		10		10		12		9
>50'		14		17		14		11
AVE DBH (in)		32		32		29		38
# cavities/ac[3]		11		8		11		16
TOTAL SNAGS		46		48		52		35
# plots		294		106		111		77
				FALLEN TREES				
Condition 1[2]	2.26	10	1.47	8	2.90	14	2.49	8
2	24.49	152	23.75	167	23.97	169	26.45	104
3	21.50	203	21.39	207	16.11	237	30.02	145
Size 1[4]	1.91	193	2.14	232	2.27	212	1.00	104
6	4.39	98	4.53	92	5.34	123	2.68	70
12	9.13	50	6.67	35	11.12	64	9.79	50
20	32.84	25	33.28	24	24.25	21	45.49	33
TOTAL FALLEN TREES	48.26	366	46.61	382	42.99	420	58.96	257
# plots		192		72		73		47

1. Standing dead trees ≥10" DBH and ≥10' tall.
2. See text for description of condition classes for snags and fallen trees.
3. Cavities are openings usable by birds or small mammals
4. See text for description of size classes for fallen trees.

Table 7. Features of snags on the Gifford Pinchot National Forest by plant association. Mean and standard deviation (in parentheses) of snag number per acre by height and decay condition classes (defined in text) and snag diameter at breast height (DBH) and number of cavities potentially usable by wildlife.

ASSOCIATION	# PLOTS	TOTAL SNAGS /ACRE	CAV'S PER ACRE	SNAG AVE DBH	SNAGS/AC BY HT(ft) 10-30	30-50	> 50	SNAGS/ACRE BY CONDITION CLASSES 1	2	3	4	5
TSHE/LYAM	1	11	4	45	11	0	0	0	0	0	0	11
TSHE/ATFI	7	28	5	40	21	0	6	0	18	6	2	2
		(26)	(6)	(9)	(22)	0	(7)	0	(26)	(7)	(3)	(4)
TSHE/OPHO/POMU	16	34	36	39	12	5	17	0	17	4	5	8
		(38)	(99)	(10)	(12)	(9)	(23)	(1)	(35)	(9)	(8)	(10)
TSHE/VAAL/OXOR	1	20	22	46	9	0	12	0	0	0	12	9
TSHE/POMU-OXOR	13	33	39	35	18	6	9	0	7	3	5	11
		(39)	(109)	(17)	(30)	(9)	(13)	(0)	(11)	(9)	(8)	(16)
TSHE/TITR	26	99	9	38	41	32	25	6	44	16	14	19
		(128)	(10)	(10)	(60)	(62)	(40)	(16)	(66)	(40)	(31)	(27)
TSHE/POMU	16	38	4	42	23	5	6	2	12	10	6	7
		(42)	(4)	(16)	(37)	(9)	(12)	(8)	(29)	(15)	(12)	(12)
TSHE/BENE/POMU	13	37	6	35	20	4	14	0	6	10	11	11
		(29)	(8)	(18)	(19)	(6)	(24)	(0)	(14)	(20)	(16)	(16)
TSHE/VAAL/COCA	11	34	4	40	13	9	12	4	8	5	5	14
		(30)	(5)	(8)	(16)	(8)	(13)	(6)	(8)	(6)	(7)	(13)
TSHE/VAAL-GASH	8	24	2	30	5	11	10	2	4	5	2	10
		(19)	(5)	(5)	(14)	(4)	(10)	(6)	(5)	(9)	(6)	(17)
TSHE/ACTR	86	44	9	30	17	9	18	8	20	9	6	4
		(56)	(18)	(13)	(28)	(18)	(41)	(25)	(39)	(19)	(13)	(8)
TSHE/BENE	29	60	8	29	27	13	20	2	20	20	7	10
		(45)	(7)	(12)	(27)	(19)	(33)	(7)	(37)	(25)	(14)	(13)
TSHE/BENE-GASH	35	40	5	29	23	8	10	7	17	8	4	7
		(44)	(7)	(12)	(28)	(20)	(19)	(21)	(34)	(15)	(7)	(16)
TSHE/GASH	18	55	7	23	35	13	7	1	16	13	12	12
		(68)	(11)	(8)	(54)	(22)	(12)	(4)	(26)	(47)	(21)	(17)
TSHE/CONU/ACTR	9	34	47	23	26	8	3	1	21	5	2	4
		(57)	(100)	(0)	(65)	(4)	(8)	(1)	(47)	(9)	(3)	(8)
TSHE-PSME/HODI	7	24	9	18	7	21	0	1	7	11	1	3
		(28)	(16)	(0)	(11)	(21)	(0)	(3)	(19)	(23)	(3)	(9)
TSHE-PSME-ARME	2	0										

Snag Management Considerations

Neitro et al. (1985, p 163) list fifteen very useful specific recommendations for snag management. Land managers should consult this valuable report. It is clear that we are only beginning to catalog wildlife needs. Our data provide a baseline of relatively undisturbed stands spread across the entire Western Hemlock Zone for future comparison of managed stand properties and wildlife utilization studies. Two conclusions should be emphasized. First, there are many more snags in natural stands than would occur in intensively managed forest lands lacking snag management policies. Second, most snags lack cavities. This could indicate that only a proportion of the available snags are suitable for wildlife use or perhaps that there is an oversupply of snags for existing population use. Better information regarding wildlife habitat needs and the habitat availibility in managed stands will allow land managers to assess the impact of our snag management policies.

Fallen Trees

Down, dead trees form a very conspicuous part of the forest throughout the Western Hemlock Zone. This material includes all sorts of tree parts, ranging from twigs, broken branches, tree boles, stumps and root wads. Besides representing fuel for wildfires, this woody debris has a number of important ecosystem functions. Down logs may provide the primary and secondary habitat for 150 wildlife species in the western Cascades of Washington and Oregon (Bartals et al. 1985). Some of these species have ecosystem roles critical to forest productivity, such as spreading essential mycorrhizal fungi or feeding on insect pests. Woody debris also is home to many invertebrates and even nitrogen fixing microorganisms which can help enrich the ecosystem with this critically limiting element (Maser and Trappe 1984). Large down logs may be essential seedbeds in excessively moist areas where soils are unsuitable for many conifers. Tree rooting in woody debris may provide nutrients and even essential moisture during periods of summer drought when the spongy tissue of well-rotted logs may yet be moist long after the mineral soil has dried. Upland slopes may be partially stabilized by down logs. Woody debris is also critical to the structure of streams flowing through forested areas. Our understanding of the roles of fallen trees in the ecosystem has only just begun.

We utilized the plane intersect method of Brown (1974) to measure down woody debris on our plots (except Wind River

RD). We measured fine fuels (< 3 inch diameter) and larger pieces separately. The fine fuels are categorized as 1-hour (< 1/4 inch diameter), 10-hour (1/4 to 1 inch diam.) and 100-hour (1-3 inch diam.) fuels (Deeming et al. 1978). This material ignites quickly so its abundance indicates wildfire danger.

Larger pieces of down wood (> 3 inch diameter) were tallied according to size and deterioration condition classes. Diameter and length were also recorded, thus allowing us to calculate total volume and weight. The size classes used in this study are:

<u>Fallen Tree Size Classes</u>

Size 1 - Piece does not contain a segment which is at least 6 inches in diameter for a length of at least 5 ft.
Size 6 - Piece contains a segment which is 6 inches in diameter or larger for a length of at least 5 ft.
Size 12 - Piece contains a segment which is 12 inches in diameter or larger for a length of at least 5 ft.
Size 20 - Piece contains a segment which is 20 inches in diameter or larger for a length of at least 5 ft.

Condition classes indicate relative states of decomposition, and are modified from Maser et al. (1979), as follows:

<u>Fallen Tree Condition Classes</u>

Condition 2 - Intact bark and wood. Fine branches present. (Maser et al. condition class 1)
Condition 2 - Bark loose, fine branches absent, wood intact or partly soft, slightly sagging. (Maser et al. condition class 2)
Condition 3 - Bark usually absent, no fine branches, wood soft to powdery, may be somewhat oval in cross-section, all of piece is on ground. (Maser et al. condition classes 3 and 4)

We did not tally highly decomposed pieces (Maser et al. (1979) condition class 5) in this study; this should be kept in mind in comparing our data with those from other studies (see review by Harmon et al. 1986).

The average weight of down woody debris greater than 3 inches in diameter for all plots was 48.26 tons/acre (1 ton/acre=2242 kg/hectare) (Table 6). Most of this biomass was of the largest size category. Relatively little woody debris mass is small pieces or pieces exhibiting little decay (decay condition one). The number of pieces per acre is very high for the smaller size classes. Overall, only 10 pieces per acre were found in the least rotted condition class.

The distribution of down woody debris by the seral stage (either < 100 yrs, 100-200, or >200 yrs) of the stand illustrates that the younger stands have a much greater contribution of both biomass and piece density in the small size classes than in the later seral stage (Table 6). The weight and density of large pieces is highest in the late seral stands. These large pieces are the ones which have great value for wildlife and plant rooting. Most of these late seral stands can be considered to be old-growth (Franklin et al. 1981). It is interesting to note that on average the early seral stands had considerably more of the largest debris than did the mid-seral stands . Much of this is probably carry-over material from the forest antecedent to the young seral stands. Our future managed stands will only have that biomass of large woody debris which we leave behind, hence the need for careful evaluation of management practices on this important but poorly understood ecosystem component.

The distribution of different sized down woody debris by plant association illustrates how variable this information is (Table 8). Overall, the dry associations appear to have smaller amounts, perhaps because of greater intensity or frequency of wildfire before the stands were initiated. The dryer associations are also less productive, so larger trees take longer to grow and are thus less likely to contribute to the debris layer. These data are presented merely to indicate the range occurring in natural Western Hemlock Zone stands. They should not be used for predictive purposes. Site specific factors of each stand are more important in determining woody debris values than is the plant association.

The tabulation of down woody material by condition class also illustrates the high degree of variability in this information (Table 9). There is generally between a fifth to a tenth the material in condition class 1 as in class 2. Classes 2 and 3 have similar amounts, though the moist-site indicating associations (such as Western hemlock/devil's club/swordfern, Western hemlock/swordfern-oxalis, Western hemlock/foamflower) generally have much more condition 3 than condition 2 woody debris. The condition 1 materials have all been recently dropped and they decay rather rapidly to condition class 2. The condition class 2 materials decay more slowly into class 3. Some of the class 3 materials may be remnants of the previous stands. Note that the very

Table 8. Fine fuels and down woody material (DWM) weights by association on the Gifford Pinchot National Forest. Means and standard deviations (in parentheses) of tons(English)/acre and the number of large logs (>20 inch diam.) per acre.

ASSOCIATION	# PLOTS	TWIGS <1/4" TON/AC	TWIGS 1/4-1" TON/AC	TWIGS 1-2.9" TON/AC	DWM 3-5.9" TON/AC	DWM 6-11.9" TON/AC	DWM 12-19.9 TON/AC	DWM > 20" TON/AC	DWM > 20" #/ACRE
TSHE/LYAM	1	.9	.7	.8	1.0	6.0	14.0	39.0	17
TSHE/ATFI	6	.7 (.2)	.7 (.2)	.8 (1.0)	1.0 (1.2)	4.8 (2.5)	17.8 (6.1)	18.8 (11.5)	18 (13)
TSHE/OPHO/POMU	14	.8 .50	.9 .49	1.4 1.09	4.1 10.43	3.2 3.30	5.1 5.14	50.8 (53.5)	37 (26)
TSHE/POMU-OXOR	9	.7 (.4)	1.0 (.4)	2.1 (.9)	1.8 (1.2)	5.3 (3.6)	9.4 (7.3)	31.7 (22.3)	26 (20)
TSHE/VAAL/OXOR	1	.4	.2	.8	0	1.0	12.0	44.0	15
TSHE/TITR	19	.7 (.3)	.8 (.2)	1.6 (1.5)	1.7 (1.9)	4.6 (4.0)	12.3 (9.3)	45.8 (57.5)	29 (30)
TSHE/POMU	11	.9 (.5)	.9 (.4)	1.8 (1.3)	1.7 (3.0)	5.6 (2.6)	12.4 (7.5)	49.7 (32.0)	50 (44)
TSHE/BENE/POMU	5	.8 (.6)	1.0 (.6)	1.4 (.9)	1.4 (.6)	7.6 (5.2)	7.8 (6.0)	40.2 (37.4)	29 (29)
TSHE/VAAL/COCA	5	.8 (.5)	.6 (.3)	1.0 (1.1)	0 0	2.8 (3.3)	9.0 (6.4)	49.0 (24.1)	63 (36)
TSHE/VAAL-GASH	3	.7 (.3)	.8 (.2)	3.5 (4.5)	1.7 (1.5)	3.0 (1.7)	19.3 (11.0)	43.7 (42.0)	20 (23)
TSHE/ACTR	47	.9 (.5)	1.1 (.7)	1.7 (1.3)	1.7 (2.1)	3.7 (3.5)	10.4 (9.5)	41.3 (76.7)	26 (36)
TSHE/BENE	30	.8 (.4)	1.2 (.6)	2.0 (1.5)	2.5 (3.5)	4.5 (3.7)	6.5 (6.8)	21.8 (26.8)	27 (36)
TSHE/BENE-GASH	26	.8 (.4)	.9 (.5)	1.4 (1.2)	2.3 (2.5)	4.8 (5.2)	5.7 (5.6)	21.5 (26.0)	15 (20)
TSHE/GASH	16	.9 (.4)	1.1 (.7)	1.4 (1.5)	1.2 (1.8)	4.1 (4.9)	8.0 (8.0)	5.1 (13.9)	5 (14)
TSHE/CONU/ACTR	1	.7	.7	.8	1.0	5.0	7.0	0	0
TSHE-PSME/HODI	1	.8	.6	1.9	1.0	13.0	9.0	28.0	10
TSHE-PSME-ARME	2	.5 (.1)	.6 (.2)	1.3 (.8)	.5 (.7)	0 (0)	2.0 (2.8)	0 (0)	0 (0)

Table 9. Down woody material by decay condition class (defined in text) for Western Hemlock Zone plant associations on the Gifford Pinchot National Forest. Means and standard deviations (in parentheses) of weight, volume and number of pieces per acre.

ASSOCIATION	# PLOTS	WEIGHT IN TONS/ACRE CONDITION CLASS 1	2	3	VOLUME IN CUBIC FEET/ACRE CONDITION CLASS 1	2	3	# PIECES/ACRE CONDITION CLASS 1	2	3
TSHE/LYAM	1	0	0	60	0	0	6317	0	0	206
TSHE/ATFI	5	7 (8)	24 (10)	11 (4)	593 (640)	2153 (842)	1178 (528)	19 (19)	180 (154)	168 (91)
TSHE/OPHO/POMU	12	2 (4)	20 (20)	42 (42)	159 (367)	1799 (1839)	4431 (4519)	4 (9)	182 (349)	214 (188)
TSHE/POMU-OXOR	9	4 (10)	14 (16)	31 (18)	303 (873)	1257 (1470)	3265 (1921)	17 (41)	181 (126)	312 (270)
TSHE/VAAL/OXOR	1	0	12	45	0	1175	4781	0	104	111
TSHE/TITR	19	.3 (1)	35 (43)	29 (27)	30 (95)	3210 (3928)	3077 (2843)	6 (9)	160 (194)	283 (320)
TSHE/POMU	11	5 (10)	32 (22)	33 (25)	397 (854)	2926 (2030)	3482 (2664)	12 (23)	175 (152)	242 (118)
TSHE/BENE/POMU	5	.4 (.5)	40 (32)	17 (11)	42 (58)	3640 (2936)	1759 (1187)	2 (3)	184 (126)	195 (191)
TSHE/VAAL/COCA	5	0 (0)	22 (19)	39 (31)	0 (0)	2009 (1714)	4164 (3321)	0 (0)	54 (65)	204 (131)
TSHE/VAAL-GASH	3	0 (0)	41 (22)	27 (16)	0 (0)	3711 (2048)	2855 (1720)	0 (0)	111 (76)	127 (46)
TSHE/ACTR	47	2 (8)	32 (63)	23 (30)	191 (660)	2882 (5767)	2463 (3221)	8 (23)	145 (130)	157 (117)
TSHE/BENE	30	2 (7)	19 (20)	14 (15)	179 (568)	1729 (1848)	1541 (1576)	10 (35)	179 (185)	281 (275)
TSHE/BENE-GASH	26	3 (6)	22 (23)	10 (11)	219 (511)	2007 (2100)	1017 (1205)	8 (9)	177 (170)	170 (248)
TSHE/GASH	16	2 (4)	7 (8)	10 (10)	122 (321)	657 (678)	1015 (1078)	9 (21)	78 (74)	131 (132)
TSHE/CONU/ACTR	1	2	6	5	151	525	642	3	143	234
TSHE-PSME/HODI	1	3	27	21	242	2397	2257	9	72	266
TSHE-PSME-ARME	2	0 (0)	2 (3)	0 (0)	0 (0)	233 (315)	0 (0)	0 (0)	76 (107)	0 (0)

decomposed materials (class 5 of Maser et al. 1979) were not sampled. Weight, volume and pieces per acre values illustrate the relationships among these different ways of measuring woody debris.

Despite the variability displayed in our samples, there clearly is an abundance of down woody debris in most Western Hemlock Zone stands. The association averages for greater than 20 inch materials generally compare with the levels 4-6 of the photo series forest residue levels for larger Douglas-fir stands (Maxwell and Ward 1980). Quantities of total debris average overall in the 4-DF-4 class of Maxwell and Ward (1980). Though the plant associations are not in and of themselves good predictors of fuel loading, they may be helpful to fuel managers to evaluate fire danger. The moist-site associations have low fire ignition potential. Fuels specialists should consider using plant associations as one more tool in evaluating treatment needs. It is clear that forest managers will need to carefully weigh the risks and potential benefits of leaving residues on site as more information accumulates concerning the ecosystem roles played by dead and down woody debris. Bartels et al. (1985) have provided a useful summary of management considerations concerning dead and down woody material appropriate for the Western Hemlock Zone. This report should be consulted by land managers.

FORAGE PRODUCTION

Plant associations in the Western Hemlock Zone differ widely in their potential for forage production. We sampled fresh growth of forage on 227 intensive plots north of the Lewis River. We weighed all herb species as a sample and the current year's growth of individual shrub species up to a height of six feet. Three clip plots were done on each study plot and averaged. Table 10 displays the amount of forage by plant association. Note that the values are fresh, green weights. Dry weights would be approximately 5-20 per cent of these wet weights. The herb productivity of the very moist and mesic associations is striking. Western hemlock/Ladyfern averaged 1701 pounds per acre of all herb species. Western hemlock/Devil's club /Swordfern and Western hemlock/Swordfern-Oregon oxalis also had very high herb forage production. Two of the driest associations (TSHE/CONU/ACTR and TSHE-PSME/HODI) are found almost exclusively on the southern portion of the Wind River Ranger District where we have not yet sampled forage production.

Herb species differ widely in their value as forage for different species of wildlife. Most herb species are utilized to some extent by deer; swordfern and bracken fern being important exceptions (Crouch 1981).

Production of shrub forage is highly variable among the associations. Many shrub species of highest forage value for ungulates are not included in Table 10 because they occur in very small amounts in the closed, undisturbed forests which dominate our sample. Various species, such as elderberries, salmonberry and alders, primarily occupy riparian zones. Shrub browse likely forms the greatest portion of the diet of deer on the forest. Deer are likely to utilize many species and have seasonal preferences (Crouch 1981). Some species, such as salal, are generally not prized by deer as forage, but are nevertheless important browse because of their abundance and evergreen character. The drier plant associations, such as Western Hemlock/Dwarf Oregongrape-salal and Western hemlock/Salal, have large amounts of available browse. These sites provide important thermal protection and winter forage for deer and elk. The moist associations also produce large amounts of forage and are most critical as winter range . Dwarf Oregon grape is one of the few abundant shrub species in the Western Hemlock Zone which is seldomly used by deer (Crouch 1981).

Each association has particular attributes important to understanding its value as big-game habitat. The dry associations, especially Western hemlock/dogwood/vanillaleaf (TSHE/CONU/ACTR), Western hemlock-Douglas-fir/ oceanspray (TSHE-PSME/HODI), and Western hemlock/Salal (TSHE/GASH), are shrub rich. These associations often occur near small natural oak woodlands on the southern portion of the Forest. Small prairies and woodlands within a coniferous forest context are of very high value to deer (Crouch 1981). These areas stay snow-free for most of the year and there is a valuable juxtaposition of forage-rich openings with thermal and hiding cover. In addition, oak acorns are preferred by deer. The moist-site associations (TSHE/LYAM, TSHE/ATFI, TSHE/OPHO/POMU, TSHE/VAAL/OXOR and TSHE/TITR) have very large amounts of available forage, particularly herbs. These associations are also extremely important to big-game as winter range because of their prevalence in lower slope positions. Sites occupied by these associations are also commonly near heavily utilized riparian areas, and so can provide valuable thermal and hiding cover.

Table 10. Forage production of all herbs and selected shrub species in Western Hemlock Zone plant associations on the Gifford Pinchot National Forest. Mean weight (and standard error of the mean in parentheses) of the fresh, green vegetation (current year's growth) in pounds/acre. See Table 17 for definitions of shrub species codes.

ASSOCIATION	# PLOTS	ALL HERBS	SHRUBS ACCI	GASH	VAPA	VAAL	ROGY	COCO	OPHO	RUUR
TSHE/LYAM	1	770	80	0	0	0	0	0	167	0
TSHE/ATFI	6	1701 (459)	22 (22)	6 (6)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	17 (6)
TSHE/OPHO/POMU	13	1317 (379)	72 (33)	7 (7)	1 (.6)	6 (6)	5 (11)	0 (0)	168 (62)	27 (18)
TSHE/POMU-OXOR	11	1061 (346)	71 (36)	4 (4)	11 (9)	0 (0)	0 (0)	0 (0)	17 (17)	4 (2)
TSHE/VAAL/OXOR	1	1313	397	0	0	0	0	0	0	0
TSHE/TITR	22	620 (115)	51 (21)	.1 (.1)	10 (5)	19 (12)	2 (1)	1 (1)	0 (0)	14 (8)
TSHE/POMU	12	633 (146)	73 (69)	25 (17)	12 (7)	0 (0)	0 (0)	0 (0)	26 (26)	5 (3)
TSHE/BENE/POMU	9	584 (276)	39 (26)	69 (52)	53 (52)	0 (0)	0 (0)	0 (0)	0 (0)	11 (8)
TSHE/VAAL/COCA	7	278 (70)	15 (10)	39 (24)	65 (60)	298 (223)	0 (0)	0 (0)	0 (0)	19 (7)
TSHE/VAAL-GASH	3	308 (145)	0 (0)	122 (80)	42 (9)	29 (23)	0 (0)	0 (0)	0 (0)	7 (6)
TSHE/ACTR	56	335 (44)	27 (7)	45 (18)	7 (3)	4 (2)	6 (2)	0 (0)	.2 (.3)	16 (4)
TSHE/BENE	32	91 (25)	10 (3)	23 (14)	12 (6)	4 (4)	3 (3)	.3 (.3)	0 (0)	3 (2)
TSHE/BENE-GASH	32	162 (45)	18 (10)	114 (23)	18 (6)	6 (6)	10 (7)	3 (2)	0 (0)	26 (12)
TSHE/GASH	18	274 (69)	36 (18)	352 (75)	20 (10)	6 (6)	10 (7)	2 (2)	0 (0)	16 (7)
TSHE/CONU/ACTR	1	1120	107	38	0	0	0	53	0	37
TSHE-PSME/HODI	1	560	300	0	0	0	183	0	0	97
TSHE-PSME-ARME	2	125 (108)	100 (100)	16 (16)	0 (0)	0 (0)	4 (4)	33 (33)	0 (0)	0 (0)

The major factor affecting forage production in managed forests is the impact of timber harvest. Pioneer vegetation which follows timber harvest is very productive. The relationship between plant associations and pioneer vegetation is poorly known: our current samples have trees at least 50 years old. The overall forage production in stands of three different seral stages is summarized in Table 11. The middle stage (100-200 years) generally has the least forage. The late (> 200 years, primarily old-growth) stage has fairly high production of both herbs and shrubs. In addition, these sites have more production of foliose lichens (Franklin et al. 1981) which may be important winter browse in some instances (Hanley 1984).

Table 11. Forage production of all herbs and selected herb species by stand seral stage. Mean (and standard error of the mean in parentheses) weight of fresh, green vegetation (current year's growth) in pounds per acre. See Table 17 for definition of shrub species codes.

SERAL STAGE	# PLOTS	ALL HERBS	SHRUB SPECIES							
			ACCI	GASH	VAPA	VAAL	ROGY	COCO2	OPHO	RUUR
EARLY	86	483	41	104	17	3	9	2	5	26
(30-100 yr)		65	(9)	(22)	(6)	(2)	(3)	(1)	(4)	(5)
MID	85	330	26	46	7	4	4	1	17	3
(100-200)		58	(6)	(11)	(2)	(2)	(2)	(1)	(10)	(1)
LATE	54	629	50	37	22	50	.4	.3	19	16
(>200 yrs)		122	(19)	(16)	(9)	(30)	(.3)	(.3)	(9)	(6)

THE TIMBER RESOURCE

The Western Hemlock Zone of the Gifford Pinchot National Forest includes some of the finest timber growing lands in the National Forest system. The combination of abundant rainfall, a temperate climate and generally deep soils is nearly ideal for conifer growth. Because of the accessibility of these lower elevation lands, this zone has historically been heavily utilized for timber production. Standing volumes and productive capacity are still high within the Western Hemlock Zone, so this area will continue to be of greatest importance for timber harvest in the future. Intensive forestry practices should be of greatest economic value within this Zone. Major challenges for timber management primarily revolve around integrating harvest activities into the multiple use program of the Gifford Pinchot National Forest. The bulk of the Western Hemlock Zone is easily managed; the extreme environments indicated by the very wet and dry plant associations are exceptions.

The productive potential of lands within the Western Hemlock Zone is affected by the same phenomena which are largely responsible for the distribution and abundance of understory vegetation which define plant associations. Careful use of this plant association system affords the land manager an effective and systematic means of understanding site potential.

Tree Species Distributions

Although plant associations are defined on the basis of climax or long-term stable state vegetation, they tell us much about long-lived seral tree species such as Douglas-fir. Table 12 summarizes the major distribution of tree species throughout the Western Hemlock Zone. Western hemlock is the major climax species and Douglas-fir the major seral species in all cases. Western redcedar is prominent in all but the driest associations, though it occurs even there. All other tree species have more restricted distributions and importance within this Zone. Red alder is an important seral species in the moist associations, such as Western Hemlock/Swordfern-Oregon oxalis (TSHE/POMU-OXOR) and Western Hemlock/Swordfern (TSHE/POMU). Big-leaf maple is widespread, and though of low commercial value, is an important member of most associations because it is very different from conifers in its wildlife use and nutrient cycling functions. Noble and grand fir are two minor species which may be of considerable economic value in specific plant associations. Noble fir is uncommon within the Western Hemlock Zone, but is a useful species for regeneration in

Table 12. Distribution of tree species by association. C=Major climax species, c=minor climax species; S=Major seral species, s=minor seral species. See Table 17 for definitions of species codes.

Association	TSHE	PSME	THPL	ALUR	ACMA	ABAM	ABPR	ABGR	ARME	POTR2	LAOC	PIMO	TABR	QUGA
Wet Group:														
TSHE/LYAM	C	S	C	S	C	c		c		c				
TSHE/ATFI	C	S	C	S	c	c		c		c				
TSHE/OPHO/POMU	C	S	C	S	c									
Moist Group:														
TSHE/POMU-OXOR	C	S	C	S	c	c	s	c					c	
TSHE/VAAL/OXOR	C	S	C	S		c	s						c	
TSHE/TITR	C	S	C	S	c	c	s						c	
TSHE/POMU	C	S	C	S	C									
Mesic Group:														
TSHE/BENE/POMU	C	S	C	S	C	c							c	
TSHE/VAAL/COCA	C	S	C	s		c	s				s	s	c	
TSHE/VAAL-GASH	C	S	C			c	s				s	s	c	
TSHE/ACTR	C	S	C	s	c	c		c			s		c	
TSHE/BENE	C	S	C		c	c	s					s	c	
TSHE/BENE-GASH	C	S	C	s	c								c	
Dry Group:														
TSHE/GASH	C	S	C	s	c		s					s		
TSHE/CONU/ACTR	C	S	c		c			c						
TSHE-PSME/HODI	C	C	c		c			c					c	s
TSHE-PSME-ARME	C	C	c		c				C					

cold spots because of its cold tolerance and its very high productive potential. Grand fir may add considerable volume to stands in the dry associations: Western hemlock/ Dogwood/ Vanillaleaf (TSHE/CONU/ACTR), and Western hemlock-Douglas-fir/ Oceanspray (TSHE-PSME/HODI).

Plant Associations and Timber Management

The key silvicultural decision, that of which species to manage for, is generally quite straight-forward within the Western Hemlock Zone. Douglas-fir is the preferred commercial species in most associations. The regeneration characteristics of major tree species within this zone are summarized in Table 13. Use of genetically selected Douglas-fir stock should be the general practice. Plant associations within the Western Hemlock Zone differ in their timber management characteristics (see Table 14). The very wet associations: Western hemlock/ Skunk cabbage (TSHE/LYAM), Western hemlock/ Ladyfern (TSHE/ATFI), and Western hemlock/Devils club/Swordfern, may often be inappropriate for Douglas-fir. The use of western redcedar and western hemlock following selective harvest is preferred in these wet associations. Douglas-fir may be planted in the dry associations (listed in Table 14), but special precautions are needed for drought avoidance. These include shelterwood harvest, shade provision either

Table 13. Regeneration characteristics of major tree species in the Western Hemlock Zone (WHZ).

Species	Suitable Associations[1]	Remarks
Douglas-fir	all except TSHE/LYAM	simply stated: "the best of the west" excellent growth, high value; possible frost damage in coldest parts of WHZ; shade intolerant
West. hemlock	all except dry group	good growth, higher stand volumes in mixed species stands. good advance regen and natural seeding: heavy seed producer shade tolerant; seedlings may be damaged by heavy snow.
W. redcedar	all except dry group, plant only in wet and moist group assoc's	valuable natural addition to wide variety of environments. shade tolerant. fast growth in wet and moist assoc's but slow in dry sites. very useful to rehabilitate very moist sites.
Red alder	wet and moist groups	valuable addition to wettest sites, short-lived; heavy nitrogen fixer; out-competes conifers on wet associations
Noble fir	TSHE/VAAL/COCA, TSHE/VAAL-GASH, TSHE/VAAL/OXOR, TSHE/TITR	excellent growth, useful in potential frost pockets or frost-prone assoc's. good in mixed stands in cool and moist assoc's in WHZ.
Pacific silver fir	TSHE/VAAL/COCA, TSHE/VAAL-GASH, TSHE/VAAL/OXOR, TSHE/TITR	useful as advance regen or natural seeded in cool/moist assoc's in WHZ. Plant only in special circumstances; shade and cold tolerant.
Cottonwood	wet: TSHE/LYAM, TSHE/ATFI, TSHE/OPHO/POMU	main use for riparian area protection & rehabilitation; useful mixed in wet areas. cold tolerant; may help reduce moisture on very moist soils
Grand fir	dry group and gravelly glacial outwash areas near rivers.	useful natural addition to dry assoc's near Columbia River. shade and drought tolerant; low value but heavy volume producer. also valuable natural addition to river-bottom areas
West. white pine	TSHE/VAAL-GASH, TSHE/VAAL/COCA, TSHE/BENE, TSHE/ACTR	frost tolerant, rapid early growth; use rust resistant stock; useful in higher elevations in WHZ

1. see Table 14 for association moisture group definitions.

Table 14. Timber management characteristics of Western Hemlock Zone associations of the Gifford Pinchot National Forest.

Group Association	Regeneration: Relative Hazards: Brush Competition	Regeneration: Relative Hazards: Drought Hazard	Regeneration: Relative Hazards: Slash Disposal	Regeneration: Suitable Species: Planted	Regeneration: Suitable Species: Natural Regen.	Soil Compaction Hazard	Opportunity for Intensive Management
Wet							
TSHE/LYAM	severe	excessive moisture	avoid heavy machines	THPL,POTR2 ALRU,TSHE	THPL,POTR2,ALRU TSHE	very severe	very poor
TSHE/ATFI	severe	excessive moisture	avoid heavy machines	TSHE,THPL,POTR2, ALRU, PSME	TSHE,THPL,POTR2 ALRU	severe	poor
TSHE/OPHO/POMU	high	excessive moisture	avoid heavy machines	TSHE,THPL,POTR2 ALRU,PSME	TSHE,THPL,POTR2 ALRU	severe	poor
Moist							
TSHE/POMU-OXOR	high	low	as needed	PSME,TSHE,THPL	TSHE,THPL,ALRU	fairly high	good
TSHE/VAAL/OXOR	high	low	as needed	PSME,TSHE,THPL ABPR	TSHE,THPL,ALRU	fairly high	good
TSHE/TITR	moderate	low	as needed	PSME,ABPR,TSHE	TSHE,THPL,ALRU	moderate	excellent
TSHE/POMU	moderate	fairly low	as needed	PSME,TSHE,THPL	TSHE,THPL	moderate	excellent
Mesic							
TSHE/BENE/POMU	moderate	fairly low	avoid hot burn	PSME,TSHE	TSHE,THPL	fairly low	excellent
TSHE/VAAL/COCA	moderate	fairly low	as needed	PSME,ABPR,TSHE	TSHE,THPL	moderate	good
TSHE/VAAL-GASH	moderate	moderate	avoid hot burn	PSME,ABPR,PIMO	TSHE,THPL	low	good
TSHE/ACTR	high if burned hot	moderate	keep burn cool	PSME,TSHE	TSHE,THPL,ABGR	low	excellent
TSHE/BENE	high if burned hot	moderate	minimize burning	PSME,ABPR,PIMO	TSHE,THPL	low	good
TSHE/BENE-GASH	high if burned hot	substantial	minimize burning	PSME,TSHE	TSHE,THPL	low	good
Dry							
TSHE/GASH	moderate	substantial	minimize burning	PSME,TSHE	TSHE,THPL,PIMO	low	fair
TSHE/CONU/ACTR	high	high	careful burning	PSME,(ABGR)	ABGR,THPL,TSHE	low	good, with care
TSHE-PSME/HODI	high	severe	careful burning	PSME,(ABGR)	ABGR,THPL,TSHE QUGA	low	poor
TSHE-PSME-ARME	moderate	severe	careful burning	PSME	ARME	low	poor

with on-site slash or shade cards, and the use of planting stock from dry sites or at least from lower elevations within the seed zone.

Slash burning is a proven method of reducing fire hazard and of providing planting sites following clear-cutting. On the mesic and dry plant aassociations hot slash burning will often lead to invasion by snowbrush ceanothus (see Table 14). These sites also may suffer from nutrient depletion from hot slash burning. Regeneration of logged areas in the dry and mesic associations may also be aided by slash shading young seedlings.

Soil compaction is another hazard of intensive management. The moist and wet associations are particularly susceptible to long-term soil damage by heavy machinary operating on wet soils (see Table 14). Repeated travel by logging equipment over the same paths will cause soil compaction throughout the Western Hemlock Zone.

There are a variety of reasons for avoiding monoculture in our forests. These range from land stewardship obligations of public lands to wildlife needs to the greater productivity and disease avoidance of mixed species forests. Fortunately, several species are either effective pioneer colonizers (such as red alder and cottonwood) or effective colonizers in shady, established stands (such as western hemlock and western redcedar). Precommercial thinning activities should not unduly destroy these lower value tree species because the overall forest value may be greatest in the long-run with some diversity.
Relative productive potential is an important component of the plant association concept. Our sample plots included considerable data collection on tree heights, volumes and ages. Timber stocking data were collected from 5 variable radius plots where diameters of all count trees were measured, allowing the calculation of Stand Density Index (Reineke 1933) and stand tables. In addition, usually 5 site trees (canopy dominants) of each major species present were measured for height, age, diameter, crown ratio, sapwood thickness and surrounding basal area (for Growth Basal Area calculation, Hall 1985). These data characterize site indices and serve as inputs for various methods of stand volume and productivity computation. Our samples should be considered to be best case productivity estimates for unmanaged forests. This is because we carefully selected undisturbed sample stands and site trees were among the best on the plots.

Timber Productivity

The timber stand characteristics of our sample plots are displayed in Table 15. The values presented are based on plot averages. Thus, the site trees of each species are averaged for the plot and then the plots for each association are averaged: the standard deviation of these values is provided. Our plots represent unmanaged stand conditions; future managed stands may have different characteristics, but the relative relationships of productivity among the associations should hold true.

Stand volumes and production are highly dependent on tree age. We used several indices to compare the stocking and productivity of different aged stands (see Table 16). The first index is derived from normal yield tables that are adjusted for stocking density by their proportion of normal stand density index (SDI). This is called the SDI-based index: it reflects a very approximate estimate of the site's capability to produce timber at culmination of mean annual increment. Another index is the yield capacity at culmination of mean annual increment. This index is based on site index and normal yield tables (Tepley 1985). The other estimate of productivity is an ingrowth model of productivity during the last ten years of the stand based on our stocking and tree core data (Hemstrom 1983). This ingrowth model uses individual tree volume equations for each species. We substituted tree volume equations appropriate for the Western Hemlock Zone. Volume equations used for Douglas-fir and western hemlock came from C. Chambers (personal communication, Washington State Department of Natural Resources). This current volume increment index of productivity refers to cubic volume of total stem, and is highly dependent on stand age as well as stocking and inherent site productive potential. Growth basal area (GBA) is an index of stockability corresponding to that basal area at which trees would be expected to grow 10/20 inch in radial increment per decade at age 100 (Hall 1983). Site indices are also presented: Douglas-fir and western hemlock (base age 100) in Table 16 and all species in Appendix 2. Appendix 2 also presents species specific age, stocking and volume values for all associations and lists references to all site indices used in this paper.

The various timber indices demonstrate that the Western Hemlock Zone is indeed very productive across a wide array of associations. The excessively moist Western hemlock/ Skunk cabbage (TSHE/LYAM) is an exception to the rule of production being moisture related. Similarly, the cooler

Table 15. Current timber stand characteristics of Western Hemlock Zone plant associations. The associations are listed in order, roughly, from wet- to dry-site indicators.

ASSOCIATION		# PLOTS	AVE TREE AGE	MAX TREE AGE	TOT BASAL AREA	TREES PER ACRE	TREES/ ACRE >7"DBH	QUAD. MEAN DIAM.	STAND DENSITY INDEX	TOTAL STAND VOLUME
TSHE/LYAM	MEAN	1	104	138	200	146	146	15.8	306	6091
TSHE/ATFI	MEAN	7	130	181	271	182	126	17.6	387	10940
	STDEV		98	125	81	88	25	5.2	89	3578
TSHE/OPHO/POMU	MEAN	16	209	284	320	157	115	22.3	415	14421
	STDEV		173	247	98	128	66	7.7	103	6576
TSHE/POMU-OXOR	MEAN	48	150	180	303	185	153	20.4	417	12489
	STDEV		119	179	61	117	75	8.4	76	3878
TSHE/VAAL/OXOR	MEAN	15	131	-	283	252	198	16.9	428	9928
	STDEV		132	-	58	146	103	6.9	88	3512
TSHE/TITR	MEAN	27	209	269	370	182	134	21.9	490	16314
	STDEV		142	198	82	108	50	7.8	101	4974
TSHE/POMU	MEAN	16	165	415	322	192	153	19.8	442	13674
	STDEV		113	787	77	96	85	7.5	79	5007
TSHE/BENE/POMU	MEAN	25	165	227	289	245	158	17.1	426	10983
	STDEV		107	200	72	194	57	6.4	101	4022
TSHE/VAAL/COCA	MEAN	18	328	630	283	205	127	19.0	399	11569
	STDEV		185	229	79	217	95	6.4	116	5031
TSHE/VAAL-GASH	MEAN	10	274	366	258	132	112	20.8	351	11672
	STDEV		120	270	61	72	56	6.0	72	4534
TSHE/ACTR	MEAN	114	155	192	305	229	168	17.9	439	12219
	STDEV		105	164	73	146	82	6.3	92	4290
TSHE/BENE	MEAN	38	171	254	312	301	217	15.0	483	11549
	STDEV		112	230	68	168	98	4.2	93	3716
TSHE/BENE-GASH	MEAN	38	165	240	283	241	167	16.7	420	10780
	STDEV		117	209	75	149	76	5.7	95	4051
TSHE/GASH	MEAN	19	135	162	259	307	216	13.7	416	8970
	STDEV		103	142	76	166	99	4.7	99	3953
TSHE/CONU/ACTR	MEAN	9	161	269	275	118	96	24.5	348	12814
	STDEV		81	228	47	93	64	8.9	72	2922
TSHE-PSME/HODI	MEAN	10	130	122	274	188	151	17.5	398	10333
	STDEV		68	33	72	104	80	3.6	120	3282
TSHE-PSME-ARME	MEAN	2	279	368	284	138	72	19.5	382	11839
	STDEV		59	36	107	22	14	5.2	100	8276

Table 16. Current and potential timber productivity and current site quality indices for Western Hemlock Zone plant associations. SD is standard deviation. See text for description of these indices. McArdle et al. (1949) and Barnes (1962) are references for Douglas-fir and western hemlock site indices.

ASSOCIATION		SDI-BASED VOLUME INDEX	CURRENT VOLUME INCREMENT	MEAN ANNUAL INCREMENT @ CULMINATION	GROWTH BASAL AREA DOUGLAS-FIR	DOUGLAS-FIR SITE INDEX AGE 100	W. HEMLOCK SITE INDEX AGE 100
TSHE/LYAM	MEAN	82	114	59	408	120	-
TSHE/ATFI	MEAN	177	121	99	601	166	124
	SD	47	44	26	224	19	-
TSHE/OPHO/POMU	MEAN	192	118	94	556	172	126
	SD	64	67	46	133	21	5
TSHE/POMU-OXOR	MEAN	176	158	113	463	157	145
	SD	40	93	51	127	18	18
TSHE/VAAL/OXOR	MEAN	147	140	117	437	136	121
	SD	30	61	51	114	13	17
TSHE/TITR	MEAN	215	121	99	564	163	127
	SD	50	52	40	157	15	17
TSHE/POMU	MEAN	191	129	107	504	161	137
	SD	53	62	47	161	21	19
TSHE/BENE/POMU	MEAN	162	103	84	401	142	128
	SD	45	40	36	120	18	15
TSHE/VAAL/COCA	MEAN	130	66	52	349	135	125
	SD	34	41	37	113	22	24
TSHE/VAAL-GASH	MEAN	113	67	57	396	123	117
	SD	39	55	50	116	23	19
TSHE/ACTR	MEAN	162	116	104	402	139	120
	SD	50	59	48	136	21	19
TSHE/BENE	MEAN	152	110	87	380	125	118
	SD	48	51	42	116	21	18
TSHE/BENE-GASH	MEAN	134	99	84	381	127	117
	SD	48	52	39	137	21	16
TSHE/GASH	MEAN	118	87	85	317	117	100
	SD	46	50	42	137	17	24
TSHE/CONU/ACTR	MEAN	123	99	90	420	135	129
	SD	32	27	32	91	12	-
TSHE-PSME/HODI	MEAN	107	113	100	372	113	-
	SD	61	78	58	158	22	-
TSHE-PSME-ARME	MEAN	92	56	40	385	105	-
	SD	42	43	21	203	13	-

Alaska huckleberry associations (TSHE/VAAL/COCA and TSHE/VAAL-GASH) display lower production than the other moist associations. These lower values may be due to the great age of our samples in these two types. At the other end of the moisture gradient lies another exception, Western hemlock/Dogwood/Vanillaleaf (TSHE/CONU/ACTR). This association is quite dry and hot making regeneration difficult. However, once established, stands exhibit high productivity and stocking.

The geographically more widespread associations, Western hemlock/Vanillaleaf (TSHE/ACTR), Western hemlock/Foamflower (TSHE/TITR), and Western hemlock/Dwarf Oregon grape/Swordfern (TSHE/BENE/POMU), all have fairly high productive potential. The other two widespread associations are drier and less productive: Western hemlock/Dwarf Oregon grape-salal (TSHE/BENE-GASH) and Western hemlock/Dwarf Oregon grape (TSHE/BENE).

The more productive associations are generally those with a greater component of moist-site herbs and a lesser component of evergreen shrubs. These distributions are also related to soil depth and water-holding capacity. The upper slope positions are generally more rocky and do not receive sub-surface irrigation as do the lower slopes. Perhaps in deep soils tree roots spread out down in the soil allowing the surface soil to be utilized by herbs. Rocky soils have little usable soil volume so root competition is intense and the benefits of being evergreen (drought resistance and maximum utilization of nutrients) determine vegetation dominance.

CHAPTER 3 KEYS TO FOREST ZONES AND PLANT ASSOCIATIONS

HOW TO USE THE KEYS

The keys below are for use in relatively undisturbed, mature forest stands. A fairly homogeneous area should be used to determine plant associations, and care should be taken to avoid locating the area too close to a road, stand edge or other artificial phenomenon that would influence the species present. A good plot configuration for this purpose would be a roughly circular area between 40 and 50 feet in radius.

After selecting the plot area, a list of all species present (including trees, shrubs and herbaceous plants) should be made, and their percent cover recorded. Table 17 presents a list of all the plant species mentioned in this guide. Percent cover is determined by projecting the total crown perimeter for a species to a plane surface, then estimating the percent of the plot area it constitutes. Appendix 4 includes a helpful guide for visualizing per cent cover.

After the plot area has been thoroughly examined, the results may be run through the keys that follow. In some stands, the canopy may be so dense that the understory may be severely limited. In such cases, relative dominance rather than actual cover percentages may be used to determine p[illegible] association.

A general key to forest zones of the entire Gifford Pinchot National Forest is provided. Brief descriptions of the Forest Zones is provided. See the plant association and management guide for the Pacific silver fir zone when you are in or near that zone (Brockway et. al 1983).

Appendix 5 includes a discussion of the relationship between Forest Zones and the working groups utilized in the current Gifford Pinchot National Forest comprehensive management planning process.

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**************************************************
*                                                *
*   NOTE:  THE KEY IS NOT THE CLASSIFICATION!!!  *
*                                                *
*   Before accepting the results of keying out   *
*   an association, be sure the vegetation de-   *
*   scription  fits.  If in doubt, consult       *
*   the species tables found in Appendix 3.      *
*                                                *
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KEY TO FOREST ZONES

1a Subalpine fir $\geq$ 2% cover in understory and $\geq$ 5% cover in canopy, discontinuous forest cover Subalpine Fir Zone

1b Subalpine fir $\leq$ 2% cover in understory and < 5% cover in canopy, continuous forest cover 2

2a Mtn. hemlock $\geq$ 2% cover in understory or $\geq$ 10% cover in canopy, has continuous forest canopy . . . . . . Mountain Hemlock Zone[1]

2b Mtn. hemlock < 2% in understory and < 10% in canopy 3

3a Pacific silver fir $\geq$ 2% in understory or $\geq$ 10% in canopy . . . . Pacific Silver Fir Zone[1]

3b Pacific silver fir < 2% in understory and < 10% in canopy 4

4a Grand fir $\geq$ 2% cover in understory and $\geq$ 10% in canopy 5

4b Grand fir < 2% cover in understory and < 10% in canopy 6

5a West of Cascade crest, alluvial terrace: Western Hemlock Zone

5b East of Cascade crest or dry upland site on Wind River District: Grand Fir Zone[2]

6a Lodgepole pine $\geq$ 2% in understory and $\geq$ 10% in canopy: Lodgeole Pine Zone

6b Lodgepole pine < 2 in understory and < 10% in canopy 7

7a western hemlock present . . . **Western Hemlock Zone: see page 64**

7b western hemlock absent: go to 1 and try key again with relaxed % values. If Douglas-fir cover is > 10%, try Western Hemlock Zone Key

1. See Brockway et. al 1983, Plant association and management guide for the Pacific Silver Fir Zone, Gifford Pinchot National Forest.

2. See Mt. Adams Ranger District Grand Fir Zone plant association draft guide (in preparation).

FOREST ZONE DESCRIPTIONS

Western Hemlock Zone

This zone is moist and warm. It is ideal for the growth of trees. Dense stands of Douglas-fir invade following catastrophic wildfires. These stands include lesser amounts of red alder, western redcedar, bigleaf maple and western hemlock. Without further disturbance the Douglas-fir is replaced by western hemlock after many centuries. This zone resonds most favorably to most management activities. It provides considerable quantities of timber and is of vital importance for many wildlife species and for high quality watersheds.

Pacific Silver Fir Zone

Persistent winter snow packs help delimit this zone. It spans the gradient between the warm, moist Western Hemlock Zone and the very cold, moist Mountain Hemlock Zone. The forests are dominated by Douglas-fir and noble fir folowing large fires, but these species are eventually replaced by Pacific silver fir. This zone provides high values of many resources, but the prevailing cold climates dictate the type of management activities.

Grand Fir Zone

This zone reflects dry, continental climates with extremes in temperature and moisture. It is highly productive and offers many opportunities for wildlife, recreation and timber utilization. The relatively dry climates dictate different management strategies than in the Western Cascade areas under the maritime climatic influence.

Mountain Hemlock Zone

The harsh, high elevations include this zone. Most of the year snow-packs prevail and frost can occur at any time of the year. The forest canopy provides a generally a continuous cover. Biological processes are slow and result in fragile ecosystems. The proximity to spectacular alpine areas and the relatively open understory characteristics of the forests make this zone a favorite for many recreationists.

Subalpine Fir Zone

This zone includes the coldest and harshest forested sites near and at treeline. Snow and ice dominate the climate for much of the year. Trees generally exist in a discontinous distribution of ribbons and patches interlaced with alpine meadows.

Lodgepole Pine Zone

Many very different situations lead to the hostile environments for plant growth which characterize the Lodgepole Pine Zone. This zone is not at all widespread, but it offers special problems. It is found in sites which are either very frosty year-around, very droughty and nutrient poor (such as the Kalama Mudflow and various recent lava flows) or very moist and cold (such as high elevation bogs).

KEY TO WESTERN HEMLOCK ZONE ASSOCIATIONS

See Table 1 and 17 for English names of plant association species codes. See Halverson et al. 1986 for photos and descriptions of these species.

1a	Skunk-cabbage (LYAM) cover ≥ 2%	**TSHE/LYAM**	(p 70)
1b	Skunk-cabbage cover < 2%	2	
2a	Devil's club (OPHO) cover ≥ 3%	**TSHE/OPHO/POMU**	(p 74)
2b	Devil's club cover < 3%	3	
3a	Lady fern (ATFI) cover ≥ 5%	**TSHE/ATFI**	(p 72)
3b	Lady fern cover < 5%	4	
4a	Oregon oxalis (OXOR) cover ≥ 5%	5	
4b	Oregon oxalis cover < 5%	6	
5a	Alaska huckleberry (VAAL) cover ≥ 3%	**TSHE/VAAL/OXOR**	(p 78)
5b	Alaska huckleberry cover < 3%	**TSHE/POMU-OXOR**	(p 76)
6a	Coolwort foamflower (TITR,=TIUN) plus inside-out flower (VAHE) cover ≥ 5%	**TSHE/TITR**	(p 80)
6b	Coolwort foamflower & VAHE COVER < 5%	7	
7a	Alaska huckleberry (VAAL) cover ≥ 5%	8	
7b	Alaska huckleberry cover < 5%	9	
8a	Salal (GASH) cover ≥ 5%	**TSHE/VAAL-GASH**	(p 88)
8b	Salal cover < 5%	**TSHE/VAAL/COCA**	(p 86)
9a	Swordfern (POMU) cover ≥ 10%	10	
9b	Swordfern cover < 10%	11	
10a	Dwarf Oregon grape (BENE) cover ≥ 10%	**TSHE/BENE/POMU**	(p 84)
10b	Dwarf Oregon grape cover < 10%	**TSHE/POMU**	(p 82)
11a	Madrone (ARME) cover ≥ 2%	**TSHE-PSME-ARME**	(p 105)
11b	Madrone cover < 2%	12	
12a	Oceanspray (HODI) cover ≥ 3%	**TSHE-PSME/HODI**	(p 102)
12b	Oceanspray cover < 3%	13	

13a Vanillaleaf (ACTR) cover ≥ 10% 14
13b Vanillaleaf cover < 10% 15

14a Dogwood (CONU) cover ≥ 10% **TSHE/CONU/ACTR** (p 100)
14b Dogwood cover < 10% **TSHE/ACTR** (p 90)

15a Salal (GASH) cover ≥ 10% 16
15b Salal cover < 10% 17

16a Dwarf Oregon grape (BENE) cover ≥ 10% . . . **TSHE/BENE-GASH** (p 95)
16b Dwarf Oregon grape cover < 10% . . . **TSHE/GASH** (p 97)

17a Mesic site herbs (ACTR+ADBI+ANDE+COCA+SMST+VAHE+TITR*)
cover ≥ 5% 18
17b (ACTR+ADBI+ANDE+COCA+SMST+VAHE+TITR*) cover < 5% 19

18a Dogwood (CONU) cover ≥ 10% **TSHE/CONU/ACTR** (p 100)
18b Dogwood cover < 10% **TSHE/ACTR** (p 90)

19a Dwarf Oregon grape (BENE) cover ≥ 10% **TSHE/BENE** (p 93)
19b Dwarf Oregon grape < 10% : go back to #1
ease up on cover decision criteria
use relative cover instead of absolute canopy cover

If the plot does not fit the association description go back to the beginning of the key and check each choice carefully. Be sure you have taken the corect dichotomy.

* vanillaleaf (ACTR), pathfinder (ADBI), three-leaved anemone (ANDE) dogwood bunchberry (COCA), star-flowered Solomens seal (SMST), inside-out flower (VAHE), coolwort foamflower (TITR, =TIUN)

Table 17. List of plant species mentioned in this guidebook.

TRI CODE	SCIENTIFIC NAME	COMMON NAME	INDICATOR VALUE
TREES			
ABAM*	Abies amabilis	Pacific silver fir	cool
ABGR*	Abies grandis	grand fir	warm, dry
ABLA2	Abies lasiocarpa	subalpine fir	very cold
ABPR	Abies procera	noble fir	cool
ACMA	Acer macrophyllum	bigleaf maple	warm
ALRU	Alnus rubra	red alder	moist, warm
ARME*	Arbutus menziesii	madrone (Pacific)	hot, dry
CONU*	Cornus nuttallii	dogwood (Pacific)	warm,dry
LAOC	Larix occidentalis	larch (tamarack	cool
PICO	Pinus contorta	lodgepole pine	cold, dry
PIMO	Pinus monticola	western white pine	cool
POTR2	Populus trichocarpa	black cottonwood	moist(or cold)
PSME	Pseudotsuga menziesii	Douglas-fir	widespread
QUGA	Quercus garryana	Oregon white oak	hot, dry
TABR	Taxus brevifolia	Pacific yew	warm, ± dry
THPL	Thuja plicata	western redcedar	widespread
TSHE*	Tsuga heterophylla	western hemlock	widespread
TSME	Tsuga mertensiana	mountain hemlock	cold
SHRUBS			
ACCI	Acer circinatum	vine-maple	widespread
AMAL	Amelanchier alnifolia	serviceberry	hot, dry
ARUV	Arctostaphylos uva-ursi	bearberry(kinnikinic)	harsh
BENE*	Berberis nervosa	dwarf Oregon grape	widespread
CEVE	Ceanothus velutinus	snowberry, ceanothus	pioneer
CHUM	Chimaphila umbellata	prince's pine	
CONU*	Cornus nuttallii	dogwood (Pacific)	warm, dry
COCO2	Corylus cornuta var. Californica	California hazel	warm, dry
GASH*	Gaultheria shallon	salal	warm, dry
HODI*	Holodiscus discolor	oceanspray	hot, dry
JUCO4	Juniperus communis	common juniper	harsh
OECE	Oemeleria (Osmaronia) cerasiformis	indian plum	warm
OPHO*	Oplopanax horridum	devil's club	wet
PAMY	Pachystima myrsinites	Oregon boxwood	widespread
RILA	Ribes lacustre	prickly currant	moist
ROGY	Rosa gymnocarpa	baldhip rose	mesic, dry
RUSP	Rubus spectabilis	salmonberry	moist
RUUR	Rubus ursinus	trailing blackberry	mesic
SYMO	Symphoricarpos mollis	creeping snowberry	warm, dry
VAAL*	Vaccinium alaskaense	Alaska huckleberry	cool, moist
VAME	Vaccinium membranaceum	big huckleberry	cool
VAOV	Vaccinium ovalifolium	oval-leaf huckleberry	cool, moist
VAPA	Vaccinium parvifolium	red huckleberry	widespread

* species used in the key to plant associations in this guide

Table 17. continued

TRI CODE	SCIENTIFIC NAME	COMMON NAME	INDICATOR VALUE
HERBS			
ACRU	*Actaea rubra*	baneberry	moist
ACTR*	*Achlys triphylla*	vanilla-leaf	widespread, mesic
ADBI*	*Adenocaulon bicolor*	pathfinder	warm, mesic-dry
ADPE	*Adiantum pedatum*	maidenhair fern	wet, warm
ANDE*	*Anemone deltoidea*	three-leaved anemone	widespread
ARMA3	*Arenaria macrophyllum*	bigleaf sandwort	dry
ASCA3	*Asarum caudatum*	wild ginger	moist
ATFI*	*Athyrium filix-femina*	lady fern	wet
BLSP	*Blechnum spicant*	deer fern	wet
CLUN	*Clintonia uniflora*	queencup beadlily	cool, mesic
COCA	*Cornus canadensis*	dogwood bunchberry	cool, mesic
DIFO	*Dicentra formosa*	bleeding heart	moist
DIHO	*Disporum hookeri*	fairybells	mesic
DRAU2	*Dryopteris austriaca*	wood fern	moist
GATR	*Galium triflorum*	sweet-scented bedstraw	mesic
GYDR	*Gymnocarpium dryopteris*	oak fern	wet
HIAL	*Hieracium albiflorum*	white hawkweed	warm, dry
HYTE	*Hydrophyllum tenuipes*	Pacific waterleaf	wet
LAMU	*Lactuca muralis*	wall lettuce	warm, moist
LAPO	*Lathyrus polyphyllus*	leafy peavine	warm, dry
LIBO2	*Linnaea borealis*	twinflower	widespead, mesic
LYAM*	*Lysichitum americanum*	skunk-cabbage	wet
MADI2	*Malanthemum dilatatum*	false lily-of-the-valley	moist,cool
MIBR	*Mitella breweri*	Brewer mitrewort	moist, warm
MOSI	*Montia siberica*	Siberian montia	moist
OSCH	*Osmorhiza chilensis*	sweet cicely (mountain)	mesic
OXOR*	*Oxalis oregana*	Oregon oxalis	moist, warm
POMU*	*Polystichum munitum*	swordfern	mesic, widespread
PTAQ	*Pteridium aquilinum*	bracken fern	pioneer or dry
PYSE	*Pyrola secunda*	sidebells pyrola	cool to cold
SMRA	*Smilacina racemosa*	false Solomon's seal	mesic, warm
SMST	*Smilacina stellata*	star-flowered Solomon's seal	mesic
STCO4	*Stachys cooleyi*	betony	wet
TITR*=TIUN	*Tiarella trifoliata*	coolwort foamflower	cool, moist
TOME	*Tolmiea menziesii*	piggy-back plant	warm, moist
TRLA2	*Trientalis latifolia*	starflower	mesic
TROV	*Trillium ovatum*	trillium	mesic
VAHE*	*Vancouveria hexandra*	inside-out flower	moist, mesic
VICIA	*Vicia* species	vetch	dry, warm
VIOR2	*Viola orbiculata*	vetch violet	mesic
VISE	*Viola sempervirens*	redwoods violet	mesic
XETE	*Xerophyllum tenax*	beargrass	cool, dry

* species used in the key to plant associations in this guide

CHAPTER 4 PLANT ASSOCIATION DESCRIPTIONS

TSHE/LYAM

CHM1-21

WESTERN HEMLOCK/SKUNK-CABBAGE

Tsuga heterophylla/Lysichitum americanum

Structure and Composition

This association is found in very wet sites, and is rich in moisture-loving herbaceous species. The dominants are lady-fern, skunk cabbage, betony, a variety of sedges and rushes, wild ginger and piggy-back plant. The major shrub is vine maple. The canopy is generally a mix of Douglas-fir, red alder, western hemlock and western redcedar. Species composition in all layers (overstory, shrubs and herbs) varies considerably from site to site, as this group is somewhat of a "catch-all" for swampy Western Hemlock Zone sites. A notable feature of this association is the open, broken canopy, caused by a combination of disease-related top damage, windthrow and treeless patches of standing water. Summary vegetation data are in Appendix 3.

Often the TSHE/LYAM association is either transitional to non-forest wetland, or represents small "pockets" of swampy conditions within a larger, more mesic area.

Environment and Distribution

The TSHE/LYAM association occurs in the wettest parts of the Western Hemlock Zone. It also occurs on the Mt. Hood National Forest (Halverson et al. 1986). It is found at moderate elevations in riparian areas, such as alluvial bottoms or other wet, poorly-drained sites. There may be standing water, and soils tend to have a very high organic matter content with peat-like surface layers.

Productivity and Management

The TSHE/LYAM association represents moderate to low productivity. Stocking, standing volume and volume growth are generally lower than average (Table 18, 16 and App. 2).

Because these sites are excessively moist, decreased productivity due to soil erosion and/or compaction can result from ground disturbance. In addition, poorly aerated soils with high organic material content may be difficult to reforest following logging. Such soils are not only physically hard to work in, but may have chemical conditions unfavorable to the growth of Douglas-fir. In addition, shallow rooting may contribute to a greater potential for windthrow in certain sites. Western redcedar, red alder or black cottonwood should be used for reforestation where "swampy" conditions prevail.

TSHE/LYAM sites frequently occur as small patches within continuous western hemlock zone stands of upland associations. This pattern diversity leads to very high wildlife diversity. These moist patches may have far greater value than their small size suggests because many moisture-requiring species, such as amphibians, can use these sites as safe home bases from which they may forage into the nearby upland asociations.

Similar Associations

The TSHE/LYAM association is easily distinguished from other riparian types by the presence of skunk-cabbage. It is not likely to be confused with any other associations. The Western Hemlock/ Lady fern (TSHE/ATFI) association is also very moist but lacks the excessive water which characterizes the skunk-cabbage sites.

TSHE/LYAM has not been formally described in previous western Cascade plant association studies.

Table 18. Timber Productivity Statistics - TSHE/LYAM

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	120	-	23	22	408	294	124	-	n.d.	n.d.
Western redcedar	102	-	27	-	812	-	113	-	75	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

TSHE/ATFI

CHF4-21

WESTERN HEMLOCK/LADYFERN

Tsuga heterophylla/Athyrium filix-femina

Structure and composition

Ferns dominate the vegetation of this association. Lady fern is always present and may cover the forest floor along with swordfern. The species diversity of herbs is very high, including such moisture-loving species as deerfern, piggy-back, maidenhair fern, and Siberian montia. Shrub cover is low, especially considering how lush these sites are for plant growth. Tree canopies are also diverse in both species composition and in individual ages . Red alder is commonly abundant and may persist even in old stands. Vegetation data are summarized in Appendix 3.

Environment and Distribution

This association occupies very wet sites where soils almost never dry out. These sites are fairly cool, frequently on north aspects and on lower portions of slopes or bottom-lands. Cold air drainage from nearby highlands affects these environments. Most of our plots were in the Clear Creek and Cedar Flats area of Mt. St. Helens N.V.M. and in the north portion of Packwood Ranger District. Soils may be deep and were frequently dominated by tephra from recent volcanic events. The lushness is due to both very high incident rainfall as well as considerable sub-surface irrigation enhanced by the lower topgraphic positions so typical of this association.

Productivity and Management

The extremely abundant moisture found in Western Hemlock/ Lady fern sites leads to very high productivity of all plants. Douglas-fir growth is rapid and may continue to old age, leading to majestic old-growth stands. These stands include sub-dominant trees which also express high timber productivity, including western redcedar and red alder. Timber value of these stands is very high but the continually wet soils make careful management necessary. Soil compaction can readily occur any time of the year if heavy machinery makes repeated passes over the same ground. Brush invasion following disturbance should be expected to be rapid and vigorous leading to dense stands of salmonberry. Selective logging practices should be considered wherever this association is found. This is because of the fragile nature of these sites as well as their very high wildlife value. Shade tolerant species of conifers, such as western redcedar and western hemlock, should be considered in reforestation activities as well as for their growth as advance regeneration following selective harvest.

The moist patches represented by this association have high value for many species of wildlife. Winter range use is high and forage quality and availibility is subsantial throughout the year. During summer drought the dampness of these sites may serve a very valuable function for small animals by providing refuges from desiccation. It is likely that the high plant species diversity also helps maintain a high diversity of animals.

Similar Associations

TSHE/ATFI has not been previously described in the western Cascades of Oregon or Washington. Similar associations do exist however. The Western Hemlock/ Devil's club/ Swordfern type on the G.P. is also very moist and productive, but it has a very substantial shrub composition from a variety of species. Other moist site associations on the Gifford Pinchot National Forest are better drained than TSHE/ATFI. These include Western Hemlock/ Swordfern-Oregon oxalis (TSHE/POMU-OXOR), Western Hemlock/ Alaska huckleberry/ Oregon oxalis (TSHE/VAAL/OXOR), Western Hemlock/ Foamflower (TSHE/TITR), and Western Hemlock/ Swordfern (TSHE/POMU). None of these types are as persistently moist as TSHE/ATFI and they lack the high cover values for lady fern. The Western Hemlock/ Skunk cabbage association (TSHE/LYAM) is swampy and has such high soil water levels as to severely restrict tree growth.

Table 19. Timber Productivity Statistics - TSHE/ATFI

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	166	19	19	9	519	224	190	27	59	29
Western hemlock	124	-	12	-	350	-	177	-	81	-
Western redcedar	153	-	8	-	477	-	195	-	38	-
Red alder	110[5]	-	27	-	673	-	135	-	73	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981; Red alder, Worthington et al. 1960.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.
5. site index base age 50

TSHE/OPHO/POMU

CHS5-24

WESTERN HEMLOCK/DEVIL'S CLUB/SWORD FERN

Tsuga heterophylla/Oplopanex horridum/Polystichum munitum

Structure and Composition

The Western Hemlock/Devil's Club/Swordfern Association occurs in very moist sites where soils remain saturated throughout the year. It is characterized by devil's club and a suite of other moisture-loving plant species. These may include Oregon oxalis, coolwort foamflower and inside-out flower. Besides the high cover of swordfern, several other fern species are common and occasionally abundant. These moist-site indicator ferns are deerfern, maidenhair fern, lady fern, oak fern, and wood fern. Vine maple is abundant. The wet soils, the overall herb richness, as well as the shrubby character are what give the this association its distinctive lushness. Complete vegetation data for this association are presented in Appendix 3.

The tree canopies found in this association are about equally composed of Douglas-fir and western hemlock. Red alder, western redcedar and bigleaf maple are occasionally found. In general, the canopies are fairly open, reflecting the water-logged nature of these sites. Some of the largest trees found on the G.P. occur in old-growth stands of this association.

Environment and Distribution

The characteristic wetness of sites with this association generally has three causes: proximity to water, exceedingly high rainfall or impeded soil drainage. Our sample plots are either near the western edge of the G.P. where rainfall is highest or in lower slope and bottom topographic positions. Devil's club/swordfern sites may occur on any aspect or any slope steepness. Typical locations include slopes near watercourses or in heavy rainfall areas, or flat areas with impeded drainage. TSHE/OPHO/POMU is most frequent in low areas of the Cispus River Valley.

Productivity and Management

The Western Hemlock/Devil's Club/Swordfern association is among the most productive on the G.P. It is unlikely that water is ever limiting, even during summer drought. In fact, production may be reduced where water-saturated, oxygen-poor soils exist. Site index (at 100 years, McArdle) for Douglas-fir averaged 172 feet, the highest value of any association in this forest zone (see Tables 20 and 16 and Appendix 2). Although the total basal area and tree canopy cover found in this association is fairly low, the trees that do find suitable microsites grow rapidly and may attain large size.

This association clearly indicates that a site is excessively wet and prone to compaction and erosion if disturbed. Because of the high productivity of these sites, intensive management is tempting, yet substantial long-term reductions in productivity are possible because of fragile soils. Clearcuts should only be used with great care in this association. It may be better to exercise selective harvesting methods. Road-building in the Western hemlock/ Devil's club/Swordfern association also needs to be conducted with due regard for the fragile nature of the wet soils. When clearcut, reforestation should proceed with speed because red alder is especially likely to dominate these sites. Mountain beaver may also be abundant and can slow reforestation success. This association is heavily used by both deer and elk, including some of the heaviest winter range use. There is an abundance of quality forage, and the complex, multi-storied canopies provide exceptional hiding cover for big game. Small areas of standing water are common and provide wildlife habitat for many species. The Western Hemlock/Devil's Club/Swordfern Association has the highest wildlife value of any forest-zone association in the western hemlock zone.

Similar Associations

Western hemlock/Lady fern association is very similar and also has persistently moist soils. It is not so shrubby as TSHE/OPHO/POMU. The TSHE/POMU-OXOR, TSHE/POMU and TSHE/TITR associations are also moist site types, but they do not indicate such excessive moisture and they all lack devil's club.

The Western Hemlock/Devil's Club/Swordfern Association is closely allied with other forest communities having prominent devil's club cover described by other authors. It is very much like the Pacific Silver Fir/Devil's Club Association previously described for the Gifford Pinchot N.F. (Brockway et al. 1983) except that the absence of silver fir indicates a much warmer environment. The Western Hemlock/Devil's Club Association described in Mt. Rainier National Park (Franklin et al. 1979) is nearly identical to this type, except that in Mt. Rainier more oak fern and queencup are indicative of a slightly cooler

Table 20. Timber Productivity Statistics - TSHE/OPHO/POMU

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] ($ft^3/ac/yr$)		Current Overstory Vol. Inc.[4] ($ft^3/ac/yr$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	172	21	15	7	556	133	198	29	54	46
Western hemlock	126	5	16	9	579	384	180	9	72	50
Western redcedar	134	-	11	-	532	-	164	-	28	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

climate. The Mt. Baker-Snoqualmie N.F. probably has the exact same association as this on the G.P. N.F. The Mt. Hood N.F. (Halverson et al. 1986) has Western Hemlock/Devil's Club/Oregon Oxalis and Western Hemlock/Devil's Club/Alaska Huckleberry associations which are very much like the devil's club/swordfern type on the G.P. N.F. The Western Hemlock/Devil's Club Association on the Willamette N.F. (Hemstrom et al. 1985) differs slightly from this on the G.P. in that it lacks oak fern and Alaska huckleberry.

TSHE/POMU-OXOR — WESTERN HEMLOCK/SWORD FERN-OREGON OXALIS

CHF1-24 — *Tsuga heterophylla/Polystichum munitum-Oxalis oregana*

Structure and Composition

This association is probably the most visually appealing in of the Western Hemlock Zone. Old-growth stands of this association have huge, widely-spaced Douglas-firs, western hemlocks and western redcedars towering over a lush carpet of Oregon oxalis interspersed with swordfern. The shrub layer is usually sparse, consisting of an occasional vine maple, dwarf Oregon grape or red huckleberry. In the herb layer, other moist-site species may occur in addition to Oregon oxalis: mountain woodfern, deerfern, ladyfern, starry solomonseal, coolwort foamflower, inside-out flower and fairybells. Appendix 3 summarizes vegetation data.

Environment and Distribution

The TSHE/POMU-OXOR association is found at low to mid-elevations in the Western Hemlock zone on sites with abundant moisture and productive soils. Many of our plots with this association were in alluvial areas or moist toe slopes where fine soil particles and nutrients collect. Effective rooting depth and forest floor thickness both tend to be greater than average. In general, this association occurs on flatter slopes, although exceptions are found. It occurs mainly on the western edge of the Gifford Pinchot National Forest where rainfall is high.

Productivity and Management

The TSHE/POMU-OXOR association generally indicates productive, easy-to-manage sites. It has similarly high timber productivities as the other moist site Western Hemlock Zone associations. Productivity statistics for this association are found in Tables 21 and 16 and Appendix 2.

The presence of this association generally indicates conditions favorable for most management activities. Moisture is usually abundant, and soils tend to be deep, adequately drained, and fertile. An abundance of deerfern in stands of this association may indicate local areas of high water table, where the risk of soil erosion and compaction is high.

Table 21. Timber Productivity Statistics - TSHE/POMU-OXOR

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	157	18	14	5	463	127	176	26	64	43
Western hemlock	145	18	18	6	527	199	218	35	90	48
Western redcedar	141	7	28	10	706	119	170	10	63	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

Similar Associations

The TSHE/VAAL/OXOR (Western hemlock/Alaska huckleberry/Oregon oxalis) association has significantly more Alaska huckleberry than the TSHE/POMU-OXOR association, as well as more moist-site herbs besides Oregon oxalis. It is less productive and is restricted to the extreme western edge of the Forest.

In the TSHE/OPHO/OXOR (Western hemlock/Devil's club/Oregon oxalis) association, devil's club is present. It occurs on poorly-drained sites.

The TSHE/BENE/POMU (Western hemlock/Dwarf Oregon grape/Swordfern) and TSHE/POMU (Western hemlock/Swordfern) associations lack Oregon oxalis, may occur on steeper, rockier sites, and are quite widespread on the Gifford Pinchot National Forest.

TSHE/POMU-OXOR is common on the Mt. Hood National Forest (Halverson et al. 1986) and was described in the H. J. Andrews Experimental Forest (Dyrness et al. 1974). An analagous association occurs on the Willamette National Forest (Hemstrom et al. 1985).

TSHE/VAAL/OXOR WESTERN HEMLOCK/ALASKA HUCKLEBERRY/OREGON OXALIS

CHS6-13 ***Tsuga heterophylla/Vaccinium alaskaense/Oxalis oregana***

Structure and Composition

The vegetation of this association consists of a fairly dense shrub layer of Alaska huckleberry over a carpet of Oregon oxalis. Dwarf Oregon grape, vine maple, salal and red huckleberry also occur frequently. In the herb layer small amounts of deerfern, dogwood bunchberry, coolwort foamflower and swordfern are common. The overstory is a mix of western hemlock and Douglas-fir. Vegetation data are summarized in Appendix 3.

Environment and Distribution

This association is found in moist, cool sites with productive soils. It is very infrequent on the Gifford Pinchot National Forest. It is found at the western edge of the Forest and in the lower parts of the Mineral Block on Randle Ranger District. TSHE/VAAL/OXOR is widespread in the Bull Run drainage of the Mt. Hood National Forest (Halverson et al. 1986).

Table 22. Timber Productivity Statistics - TSHE/VAAL/OXOR

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	136	13	15	6	437	114	147	18	53	43
Western hemlock	121	17	14	5	444	104	170	32	67	53
Western redcedar	95	5	15	1	404	84	n.d.	n.d.	32	18
Noble fir	134	34	22	17	564	263	164	54	21	26

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981; Noble fir, Herman et al. 1978.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

Productivity and Management

Productivity in this association is moderate to high, although standing volume is low compared to other Western Hemlock Zone associations (Tables 22 and 16 and App. 2).

The presence of this association generally indicates conditions favorable for most management activities. Moisture is abundant, and soils tend to be deep, adequately drained, and fertile. An abundance of deerfern in stands with this association may indicate local areas of high water table, where the risk of soil erosion and compaction is high.

Similar Associations

The TSHE/POMU-OXOR (Western hemlock/Swordfern-Oregon oxalis) association is floristically similar to the TSHE/VAAL/OXOR association and to some extent their geographic distribution overlaps. But the TSHE/POMU-OXOR association lacks Alaska huckleberry and is less likely to have other moist-site herbs besides Oregon oxalis. It is also more productive and extends to lower elevations. The TSHE/VAAL/OXOR association probably indicates a cooler environment. It has not been formally desribed in previous western Cascade plant association studies.

The TSHE/VAAL/COCA (Western hemlock/Alaska huckleberry/Dogwood bunchberry) association lacks Oregon oxalis, is less productive and is more widespread in cool sites throughout the Western Hemlock Zone.

TSHE/TITR

CHF2-22

WESTERN HEMLOCK/COOLWORT FOAMFLOWER

Tsuga heterophylla/Tiarella trifoliata

Structure and Composition

The Western Hemlock/Coolwort Foamflower Association is lush with moss and herbaceous plants. Douglas-fir dominates the canopy, but western hemlock is also abundant, including high cover in the regeneration layer. Western redcedar is prominent. True firs, including Pacific silver, noble and grand, are found sporadically. Shrubs, except for moderate vine-maple cover, are relatively unimportant in this association. The herb layer usually includes swordfern; oak fern, deer fern and lady fern are occasionally seen. Coolwort foamflower (either the 1-leaved (TIUN) or 3-leaved variety) is the dominant understory plant species. Other prevalent herbs are vanilla-leaf, inside-out flower, trillium, twinflower and dogwood bunchberry. Oregon oxalis is absent. See Appendix 3 for complete vegetation data for this association.

Environment and Distribution

This plant association indicates moist sites with adequate drainage, which are on the cooler end of the sprectrum of the Western Hemlock Series. Two thirds of our plots occurred at elevations lower than 2000 feet. TSHE/TITR is particularly abundant in the low elevation portions of Mt. St. Helens N. V. M. and in the area near the western Forest boundary. It occurs on gentle slopes and benches. Table 2 summarizes physiographic data for this association. Soils are usually fairly deep, frequently dominated by tephra from Mt. St. Helens and Mt. Rainier (see Table 4).

Productivity and Management

This is among the most productive plant associations on the Gifford Pinchot National Forest. Douglas-fir and western hemlock site indices averaged 163 and 127 feet (see Tables 23 and 16 and Appendix 2). Western redcedar displayed high productivity which was maintained even by old trees.

Intensive forestry practices will be rewarded with high yields. Though these sites are fairly robust, the terrific productivity is an important resource which deserves extra protection from damage by careless operations. Though the moist soils are adequately drained, there may be periods when excessive moisture could allow soil damage to occur

Table 23. Timber Productivity Statistics - TSHE/TITR

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	163	15	13	6	564	157	185	21	50	36
Western hemlock	127	17	14	6	564	221	182	34	69	55
Western redcedar	135	28	13	3	694	318	165	44	39	29

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

from heavy machinery. Reforestation should be routine when tree planting closely follows harvest. Slash burning may be conducted as needed for fuel management. The cool and moist environment suggests that overall wildfire dangers are low in this association. This association provides an excellent opportunity for the management of western redcedar on the G.P. The herb-rich character and abundant hiding cover also indicate very high wildlife values. This deserves particular attention in the southern portions of the National Forest (south of the Lewis River) where this association is less common on the landscape.

Similar Associations

The Western Hemlock/Coolwort Foamflower Association is floristically similar to its analog in the Pacific silver fir zone, ABAM/TIUN, although the presence of Pacific silver fir indicates a colder environment (see Brockway et al. 1983). The substantial amount of coolwort foamflower and the near absence of devil's club and Oregon oxalis distinguish this type from the TSHE/OPHO/POMU and TSHE/POMU-OXOR associations. TSHE/TITR lacks the abundance of very moist site ferns found in the Western hemlock/ Lady fern (TSHE/ATFI) association.

The Mt. Baker-Snoqualmie N.F. has a similar TSHE zone association (Henderson and Peter 1981b), but on-going work may demonstrate a slightly different character. TSHE/TITR associations have not been described in Oregon (Halverson et al. 1986, Hemstrom et al. 1985) or in Mt. Rainier National Park (Franklin et al. 1979). In British Columbia, a very similar grouping, the Tiarella-Polystichum Biogeocoenotic Association, is also extremely productive (Klinka et al. 1981).

TSHE/POMU

CHF1-25

WESTERN HEMLOCK/SWORDFERN

Tsuga heterophylla/Polystichum munitum

Structure and Composition

The Western Hemlock/Swordfern Association includes warm and moist sites which have substantial herb cover dominated by swordfern. Species indicative of more moist associations, such as devil's club, Oregon oxalis and coolwort foamflower may be present, but in low abundance. Most of the fairly dense overstory is Douglas-fir, often associated with western hemlock, bigleaf maple, red alder and western redcedar. This is one of the best associations for bigleaf maple growth. Except for fairly substantial vine-maple cover, the shrub layer is usually not dense. Dwarf Oregon grape is present in small amounts. Red huckleberry and trailing blackberry also frequently occur. Salal, dogwood, Alaska huckleberry and oceanspray are occasionally present in very small amounts. Besides swordfern, three-leaved anemone, inside-out flower, sweet-scented bedstraw, trillium and pathfinder sometimes cover fairly large areas. Wet site ferns (oak fern, deer fern, lady fern) may exist sporadically. Appendix 3 summarizes vegetation data representative of this association.

Environment and Distribution

This association is found on moist sites which may recieve some sub-surface irrigation, a reflection of the concave, lower slope positions it most commonly occupies. We found it mainly at low elevations, away from the western edge of the Forest. Slope steepness on our plots averaged 40%, but this association also may occur in flat areas near streams. Physiographic data are summarized in Table 2. Steeper sites may have some bare ground caused by colluvial action.

Productivity and Management

This is another of the moist-site, high-productivity plant associations of the western hemlock zone. Douglas-fir site index (100 years, McArdle) averaged 161 feet. Tables 24 and 16 and Appendix 2 summarize productivity data from our plots.

The presence of seeps or super-saturated soils indicates that land-managers need to be cautious concerning soil

Table 24. Timber Productivity Statistics - TSHE/POMU

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	161	22	14	6	504	161	182	30	65	58
Western hemlock	137	19	13	5	431	169	202	37	38	19
Western redcedar	125	30	25	12	936	606	150	48	33	14

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

compaction or erosion due to heavy equipment or road-building. Because of the abundant moisture, red alder may become readily established on clear cuts, so prompt reforestation is a must. The general presence of deep soils and rapidly decomposing forest floor layers suggests that slash burning should have little effect on long-term productivity. The Western Hemlock/Swordfern Association provides great opportunities for intensive forest management. Tree improvement, fertilization, pre-commercial and commercial thinning are all especially appropriate when managing this association because the high timber production potential suggests that a high return on investment is likely. Because bigleaf maple and western redcedar are well represented in natural stands, sites with this association should play an important role for the long-term maintenance of these species on the Forest.

Similar Associations

The TSHE/POMU association is similar to the other moist-site types described in this paper (Western hemlock/ Devil's club/ Swordfern, Western hemlock/ Lady fern, Western hemlock/ Swordfern- Oregon oxalis, Western hemlock/ Coolwort foamflower) but it lacks an abundance of Devil's club, lady fern, Oregon oxalis or coolwort foamflower.

Similar plant associations exist on moist sites throughout much of western Washington and Oregon. Similarly named associations, which are nearly identical to our TSHE/POMU, are found in Mt. Rainier National Park (Franklin et al. 1979), on the Mt. Baker-Snoqualmie (Henderson and Peter 1981b), Willamette (Hemstrom et al. 1985) and Siuslaw (Hemstrom and Logan 1984) National Forests, and on the H.J. Andrews Experimental Forest (Dyrness et al. 1974). The TSHE/POMU-MTH association found on the Mt. Hood National Forest (Halverson et al. 1986) has a substantially lower productive potential. It occurs primarily on steep, rocky slopes and includes several plant species indicative of drier environments than TSHE/POMU occupies on the Gifford Pinchot National Forest.

TSHE/BENE/POMU

CHS1-26

WESTERN HEMLOCK/DWARF OREGON GRAPE/SWORDFERN

Tsuga heterophylla/Berberis nervosa/Polystichum munitum

Structure and Composition

This association has an herb layer dominated by swordfern and a fairly dense shrub layer of vine maple and dwarf Oregon grape. Some drier site shrubs (salal, baldhip rose and creeping snowberry) are common. The canopy is dominated by Douglas-fir, with substantial amounts of western hemlock, bigleaf maple and western redcedar. The herb layer frequently includes pathfinder, starflower, trillium, and vanilla-leaf. The occasional appearance of true dry site shrubs (California hazel and oceanspray) and the near absence of moist-site species (devil's club, Oregon oxalis, coolwort foamflower, oak fern) clearly separates this association from TSHE/POMU and the other moist-site Western Hemlock Zone associations. Complete vegetation data are displayed in Appendix 3.

Environment and Distribution

This association is found on moderately moist and warm sites which are very well drained. Lower elevations (< 2000 feet) with middle or lower slope positions predominate. Three-fourths of our plots in this association occurred on slopes greater than 30% grade. Table 2 summarizes physiographic information for this association. This association is widespread, but is especially abundant in the central portions (in an east-west direction) of the Western Hemlock Zone on the Gifford Pinchot and Mt. Hood National Forests.

Productivity and Management

This association is quite productive for timber. Western hemlock site indices were lower than Douglas-fir, though on those plots where we sampled both species, the western hemlock was of a considerably younger age class. For all plots, site index (at 100 years) averaged 142 feet for Douglas-fir and 128 feet for western hemlock. Stocking and productivity indices fall in the mid-ground of the western hemlock zone plant associations (see Tables 25 and 13 and Appendix 2 for complete summaries).

In general, this association includes sites which should respond favorably to careful timber management practices. Potential problems may result from the steep and somewhat

Table 25. Timber Productivity Statistics - TSHE/BENE/POMU

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	142	18	12	5	401	120	155	25	49	44
Western hemlock	128	15	12	5	380	152	184	29	40	15
Western redcedar	98	17	10	5	381	75	105	38	36	32

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

unstable slopes which frequently occur. Full-suspension logging systems and extra-careful road placement are warrented. Excessive soil moisture will limit logging operations only during brief periods of the year. Reforestation practices aimed at reducing the evaporative demand of seedlings, such as early spring planting and shade cards, may be required where this association occurs on steep, south-facing slopes. Bigleaf maple is common, so this association provides good opportunities for its management and conservation.

Similar Associations

The TSHE/BENE/POMU association is very similar to the TSHE/POMU association found on the G. P. NF, but the former includes a much greater abundance of species characteristic of mesic or dry sites. These species include dwarf Oregon grape (BENE), salal (GASH), baldhip rose (ROGY), and creeping snowberry (SYMO). TSHE/BENE/POMU also has consistently lower timber productivity than TSHE/POMU. The TSHE/POMU-MTH association found on the Mt. Hood National Forest is closely related and floristically very similar to TSHE/BENE/POMU, but it lacks dwarf Oregon grape and moist-site herbs (Halverson et al. 1986).

The TSHE/BENE/POMU association appears to exist with very similar characteristics on the Mt. Baker-Snoqualmie National Forest (Henderson, personal communication). It has not been described in Mt. Rainier National Park (Franklin et al. 1979) nor does it occur on the Willamette National Forest (Hemstrom, personal communication). Other Oregon National Forests also lack this association. The TSHE/ACCI/POMU type on the Siuslaw N.F. is somewhat similar but has a paucity of dwarf Oregon grape and occurs on moister sites (Hemstrom and Logan 1986).

TSHE/VAAL/COCA

CHS6-15

WESTERN HEMLOCK/ALASKA HUCKLEBERRY/ DOGWOOD BUNCHBERRY

Tsuga heterophylla/Vaccinium alaskaense/Cornus canadensis

Structure and Composition

This association has an abundance of huckleberry species, including Alaska, oval-leaf, red, and big-leaf huckleberry. Dogwood bunchberry and twinflower were present in nearly all of our plots. The canopy is dominated by Douglas-fir in younger stands and western hemlock in stands over 100 years old. Western redcedar is very common and Pacific silver fir may be found. In addition to the abundant huckleberry cover, the shrub layer is dominated by vine-maple and lesser amounts of dwarf Oregon grape and baldhip rose. Salal is common but occurs only in small amounts. Herb cover is fairly high, including dogwood bunchberry, twinflower, queencup beadlily, foamflower and vanilla-leaf. Fern species other than swordfern are almost entirely absent. Mosses cover is quite substantial. Vegetation data are summarized in Appendix 3.

Environment and Distribution

This association is in the cooler portion of the Western Hemlock Zone and may intergrade with the Pacific Silver Fir Zone. Moisture conditions are moderately high. Nearly half of our plots in this association on the Gifford Pinchot National Forest were found above 2500 feet in elevation (see Table 2). This association has a limited distribution, but usually is found on flat benches or lower slopes. It also may be found on alluvial plains or colluvial toe slopes. Cold air accumulates on these sites and may account for the presence of this association at lower elevations within the Western Hemlock Zone. The forest floor usually has intermediate surface organic matter accumulations typical of cooler environments (see Table 5). The cool, moist environment may also be responsible for the preponderance of old-growth stand conditions found in this association, demonstrating a low susceptibility to wildfires.

Productivity and Management

Relative to the rest of the Western Hemlock Zone, this association has intermediate potential productivity. Site index (at 100 years) for Douglas-fir was 135 feet and 125 feet for western hemlock. Stocking and productivity indices were in the lower midrange for this forest zone: stand density index was 399, Douglas-fir growth basal area was 349

Table 26. Timber Productivity Statistics - TSHE/VAAL/COCA

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	135	22	8	9	349	113	146	31	18	18
Western hemlock	125	24	9	4	375	153	178	47	34	28
Noble fir	131	-	5	-	347	-	160	-	n.d.	n.d.

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Noble fir, Herman et al. 1978.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

ft 2/acre, and total basal area averaged only 283 ft^2/acre. Tables 26 and 16 and Appendix 2 summarize productivity data for this association.

The likelihood of cool temperatures should be taken into account when managing sites with this association. Frost could cause reforestation problems when clear cut unit design results in impeded cold air drainage. Silviculturists should consider using planting stock from the next highest elevation seed zone, particularly when this association is encountered at low elevations (< 2000 feet). Otherwise, these sites should be able to respond favorably to most normal management regimes. Because the forest floors contain a larger amount of the soil organic matter than in other Western Hemlock Zone associations, extra caution in slash burning and machine piling following logging is needed.

Similar Associations

This association is similar to the other Alaska huckleberry dominated association described in this paper (TSHE/VAAL-GASH), but TSHE/VAAL/COCA has a more abundant herb layer and lacks an abundance of drier-site shrubs such as salal or dwarf Oregon grape. TSHE/VAAL/COCA has considerable floristic similarity to the Pacific silver fir/Alaska huckleberry association (Brockway et al. 1983), but is found in warmer sites and is less widespread. The Mount Hood (Halverson et al. 1986), Mt. Baker-Snoqualmie (Henderson and Peter 1981b) and Willamettte (Hemstrom et al. 1985) National Forests also have this association. TSHE/VAAL/COCA was not described in Mt. Rainier National Park (Franklin et al. 1979).

TSHE/VAAL-GASH

CHS6-14

WESTERN HEMLOCK/ALASKA HUCKLEBERRY/SALAL

Tsuga heterophylla/Vaccinium alaskaense Gaultheria shallon

Structure and Composition

This association has an abundance of huckleberry species, especially Alaska huckleberry and red huckleberry. Oval-leaf and big-leaf huckleberry also are very frequent. The substantial cover of salal is diagnostic. Dwarf Oregon grape, vine-maple, baldhip rose, and prince's pine are the other common shrubs. The canopy is dominated by Douglas-fir and western hemlock, but species typical of higher elevations also occur, including Pacific silver fir, noble fir and western white pine. The herb layer is usually sparse. The most common species are twinflower, dogwood bunchberry, beargrass, and bracken fern. Swordfern is in two thirds of the plots, but in only trace amounts. Moist site ferns (deer, oak, lady ferns) are nearly absent. Beargrass is more abundant in this association than elsewhere in the Western Hemlock Zone on the Gifford Pinchot National Forest. Complete vegetation data are presented in Appendix 3.

Environment and Distribution

This association includes sites with moderate moisture conditions which are fairly cool for the Western Hemlock Zone. It is most common on gentle slopes and ridges which have undulating or concave microtopography. Drainage of both cold air and water are adequate. The presence of some of the lowest elevation Pacfic silver fir suggests that this association can have colder climates than elevation alone would indicate. It is not a very common association, and mainly occurs on the western portion of the Wind River Ranger District and within the Bull Run River drainage on the Mt. Hood National Forest. Physiographic data for this association are summarized in Table 2.

Productivity and Management

Compared to most of the rest of the Western Hemlock Zone, this association has relatively low forest productivity. Douglas-fir site index (at 100 years, McArdle) was lower than all but the driest of the western hemlock zone types; it averaged 123 feet. Western hemlock is quite abundant and nearly as productive as Douglas-fir. It had an average site index (at 100 years) of 117 feet. On the one plot where we encountered noble fir we found it to have excellent growth.

Table 27. Timber Productivity Statistics - TSHE/VAAL-GASH

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] ($ft^3/ac/yr$)		Current Overstory Vol. Inc.[4] ($ft^3/ac/yr$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	126	23	8	5	396	116	129	33	36	46
Western hemlock	117	19	7	2	295	120	164	37	31	21
Noble fir	159	-	20	-	395	-	204	-	60	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Noble fir, Herman et al. 1978.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

This association is a good place to plant noble fir occasionally and western hemlock frequently, as well as Douglas-fir. Timber productivity indices are moderate to low (see Tables 27 and 16 and Appendix 2)), as in the other Alaska huckleberry dominated western hemlock zone type.

Opportunities for benefits from intensive forestry practices, such as tree improvement, pre-commercial and commercial thinning, are good. Management concerns include the possibility of frost and reduced growth due to cool temperatures, even at lower elevations. High stocking levels should not be demanded as these sites likely can not support them. More stems will result in less volume per bole at harvest than in other, more productive, Western Hemlock Zone associations. Pre-commercial thinning should not discriminate against western hemlock. This association may respond to slash burning with considerable shrub re-growth, so reforestation needs to proceed rapidly. The gentle slopes where this association is usually found are suitable for tractor logging, but considerable care needs to be exercised so as not to compact soils and further reduce the productive capacity of these sites.

Similar Associations

This association is an herb-poor relative of the TSHE/VAAL/COCA type: the main difference being the substantial cover of salal in TSHE/VAAL-GASH. The abundance of Alaska huckleberry distinguishes it from the other associations having considerable salal: TSHE/BENE-GASH and TSHE/GASH. The silver fir zone analog (ABAM/VAAL-GASH) has very similar floristics and relative productive potential (Brockwqay et al. 1983).

The Mt. Baker-Snoqualmie (Henderson and Peter 1981b) National Forest also contains this plant association. It was not described in Mt. Rainier National Park (Franklin et al. 1979) nor on the Willamette National Forest (Hemstrom et al. 1985).

TSHE/ACTR

CHF2-21

WESTERN HEMLOCK/VANILLA-LEAF

Tsuga heterophylla/Achlys triphylla

Structure and Composition

This association includes the productive heart of the Gifford Pinchot National Forest. It is very widespread within the Western Hemlock Zone. Tree cover is predominantly Douglas-fir with western hemlock having greater importance in old stands. Western redcedar is occasionally abundant. Both grand fir and Pacfic yew also were found on some of our plots. The grand fir is found either on relatively hot and dry sites or on alluvial plains with gravelly soils, such as near the Lewis and Cispus Rivers. Moist-site species, such as devil's club, Oregon oxalis and oak fern, are essentially absent. Swordfern is usually present but always in small amounts. A diverse assemblage of herbs constitute a substantial portion of the understory vegetation. These range from moderately-moist site affiliates (such as inside-out flower and star-flowered Solomon's seal) to moderately-dry site indicating species: bigleaf sandwort, white hawkweed and grass species. Vanillaleaf is virtually always present; it is often accompanied by pathfinder, three-leaved anemone, starflower, trillium and twinflower. Shrub cover can be quite high, but if so, it is in conjunction with high cover of the herb species mentioned above. Vine-maple and dwarf Oregon grape are prevalent. Baldhip rose, creeping snowberry, red huckleberry and California hazel are also frequently present but with less cover. Salal occurs in small amounts. In general, sites in this association having greater than 10% cover of dwarf Oregon grape exhibit lower timber productivity and have floristics indicative of slightly drier environments than sites where dwarf Oregon grape is not abundant. The diagnostic feature of the Western Hemlock/Vanillaleaf association is the plethora of mesic-site herb species and the lack of shrubs common to either very moist or very dry environments. Appendix 3 contains complete vegetation data for this association.

Environment and Distribution

This association indicates well-drained, fairly warm upland forest sites. Generally it represents moderate environmental conditions, except for potentially hot and dry situations on south-facing slopes. Water-logged soils and cold temperatures should almost never interfere with logging or reforestation operations. This association is located mostly on slopes, usually with grades greater than 30%. Soils are generally fairly deep and not very rocky. On the G. P. NF this association may be found at all elevations within the Western Hemlock Zone; it is more common on the southern part and is uncommon on the western part of the Forest. Table 2 summarizes physiographic information for this association.

Productivity and Management

Stands of this association attain highly productive levels without substantial management problems. Stocking and productivity indices are usually quite high, though variation occurs. The average site index (at 100 years) was 140 feet for Douglas-fir and 120 feet for western hemlock. The stand density index value of 439 and average total basal area of 305 ft^2/acre are among the highest of any Western Hemlock Zone association. See Tables 28 and 16 and Appendix 2) for more timber productivity information.

Table 28. Timber Productivity Statistics - TSHE/ACTR

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	139	21	12	6	402	136	152	30	64	52
Western hemlock	120	19	12	5	416	156	169	38	35	20
Western redcedar	116	27	13	4	505	221	143	53	35	37
Cottonwood	165	21	24	5	723	30	228	35	33	47
Grand fir	122	34	13	10	431	208	127	48	45	42
Red alder	77[5]	-	10	-	291	-	79	-	36	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar & cottonwood, Hegyi et al. 1981; Noble fir, Herman et al. 1978; Grand fir, Cochran 1979; red alder, Worthington et al. 1960
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.
5. site index age 50

This association includes much of the best land suitable for timber management on the G.P. Intensive forestry practices yield high benefits and the potential for site degradation following careful management activities is relatively low. Major potential management concerns result from occasional steep slopes and relatively dry conditions. Some sites within this association share, to a lesser degree, the drought conditions of dry-site Western Hemlock Zone associations. Managers need to be alert to such dry conditions on very steep or south-facing slopes, where shade cards and harvest unit design maximizing shade are appropriate. Shrub competition may also cause reforestation problems. This can result from rapid reinvasion by established brush following logging or from invasion, particularly by snowbrush ceanothus, after slash burning.

TSHE/ACTR is geographically widespread in the lower elevation portions of the Western Hemlock Zone and comprises a substantial portion of the winter range found on this National Forest. Browse production and the relatively long snow-free season also provide benefits to ungulates. Visual values may also be high as this association covers much of the highly visible mid-slopes of the lower elevations.

Similar Associations

The relative absence of the more severe-site indicating species is what helps distinguish this association. Dwarf Oregon grape may be abundant, but if so, it is in combination with several herb species and so is distinguished from the TSHE/BENE association. There is always less salal than in the TSHE/BENE-GASH and TSHE/GASH associations. TSHE/ACTR occurs in much warmer and drier environments than the Pacific Silver Fir/ Vanillaleaf-Queencup Beadlily Association previously described on the G.P. (Brockway et al. 1983).

This association is widespread throughout most of the western Cascades of Washington and Oregon. Very similar types exist in Mount Baker-Snoqualmie N.F. (Henderson and Peter 1981b), Mt. Rainier National Park (Franklin et al. 1979), and Willamette N.F. (Hemstrom et al. 1985).

TSHE/BENE

CHS1-25

WESTERN HEMLOCK/DWARF OREGON GRAPE

Tsuga heterophylla/Berberis nervosa

Structure and Composition

The TSHE/BENE association is a very herb-poor type. The shrub layer consists of a moderate cover of dwarf Oregon grape and vine maple, sometimes with traces of other species (including red huckleberry, salal and Prince's pine). The herbaceous layer may have a fair amount of twinflower, but only traces of other herbs, such as rattlesnake plantain, redwoods violet and vanillaleaf. The overstory is a mix of Douglas-fir and western hemlock, often with western redcedar in addition.

Environment and Distribution

The TSHE/BENE association appears to represent sites that are somewhat drier and cooler than average for this forest zone. It was consistently the highest elevation association found within the Western Hemlock Zone. Upper and mid-slope positions predominate. The eastern portions of the Randle Ranger District favor this association. It was not sampled on the Wind River District, though it is present there in small amounts. TSHE/BENE is also found on the Mt. Hood National Forest (Halverson et al. 1986).

Productivity and Management

Productivity is moderate in the TSHE/BENE association. Tables 29 and 16 and Appendix 2 give productivity statistics from our data set.

Because it generally occurs on soils with high rock content, plantability may be restricted in some sites with the TSHE/BENE association.

A major challenge to reforestation efforts in this type is presented on slopes with droughty soils, particularly on south-facing aspects. In such sites, consideration of artificial shade in clearcuts is recommended. The forest floor tends to be thick in the TSHE/BENE association, and efforts to avoid its destruction with slash burning will help maintain site productivity. Hot slash burning may also encourage the establishment of dense shrub stands.

Table 29. Timber Productivity Statistics - TSHE/BENE

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] ($ft^3/ac/yr$)		Current Overstory Vol. Inc.[4] ($ft^3/ac/yr$)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	125	21	10	6	380	116	131	30	44	46
Western hemlock	118	18	12	3	258	156	166	36	44	24
Western redcedar	124	15	9	3	455	43	154	25	36	10

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

Similar Associations

In the TSHE/BENE-GASH (Western hemlock/Dwarf Oregon grape-Salal) association, salal is abundant. It generally occurs in less rocky sites than the TSHE/BENE association, and is more common throughout the Western Hemlock Zone on the Gifford Pinchot National Forest. The Western hemlock/ dwarf Oregon grape/ swordfern association (TSHE/BENE/POMU) is more moist, productive and warm than TSHE/BENE. The Pacific silver fir/ dwarf Oregon grape association has similar floristics, but exists in a colder environment and includes other species characteristic of higher elevations (Brockway et al. 1983).

The TSHE-PSME/HODI (Western hemlock-Douglas-fir/Oceanspray) association is somewhat similar floristically but can be separated from TSHE/BENE by the presence of dry-site species such as oceanspray, serviceberry, tall Oregon grape, bigleaf sandwort and/or white hawkweed.

The TSHE/ACTR (Western hemlock/Vanillaleaf) association is richer in moist-site herbs, such as starry solomonseal, vanillaleaf and coolwort foamflower. It is also more productive and occurs in sites with finer-textured soils.

TSHE/BENE is widespread throughout the western Cascades of Oregon and Washington. It occurs on the Mt. Hood National Forest (Halverson et al. 1986). It has been described in the Mt. Baker Snoqualmie (Henderson and Peter 1981b) and Willamette National Forests (Hemstrom et al. 1985). It was not described for the Mt. Rainier National Park (Franklin et al. 1979). A TSHE/BENE plant association has been described by Hemstrom and Logan (1986) for the Oregon Coast Range. It differs from ours in having a well-developed herb layer of swordfern, and is more productive.

TSHE/BENE-GASH

CHS1-27

WESTERN HEMLOCK/DWARF OREGON GRAPE-SALAL

Tsuga heterophylla/Berberis nervosa-Gaultheria shallon

Structure and Composition

Large amounts of salal and dwarf Oregon grape usually dominate the understory of this shrub-rich association. Vine-maple is common and may form a fairly dense sub-canopy. Red huckleberry and baldhip rose are frequent but with low cover values. The occasional presence of the warm and dry-site shrubs, creeping snowberry, California hazel, oceanspray and serviceberry is noteworthy . Herb cover is fairly sparse but always present, and can include a wide array of mesic-site species. These include vanillaleaf, swordfern, twinflower, bracken fern, redwoods violet, starflower, pathfinder and trillium. Tree cover is very typical for the Western Hemlock Zone: Douglas-fir and western hemlock dominate. Western redcedar and bigleaf maple are common as co-dominates or sub-canopy individuals. Regenerating western hemlock are usually present in at least trace amounts and Douglas-fir seedlings may be found in some cases. Pacific silver fir was in a few of our study plots. See Appendix 3 for complete vegetation data.

Environment and Distribution

This association is very widespread on ridges and upper slopes throughout the Western Hemlock Zone, especially on Packwood Ranger District. The environment typical for TSHE/BENE-GASH most frequently is found in the central and eastern portions of the Forest which have a generally drier climate. This association can be encountered at almost any elevation where the Western Hemlock Zone can exist, but it is usually found below 2500 feet in elevation. Southern and western aspects predominate. The microtopography is frequently convex, with concavities being rare. Slopes are steep, commonly greater than 50%. Physiographic data are summarized in Table 2.

Productivity and Management

This association is clearly less productive than the moist-site western hemlock associations, though it still includes quality commercial forest land. Site indices (at 100 years) averaged 127 feet for Douglas-fir and 117 feet for western hemlock. Values for productivity indices (see Table 16, Appendix 2 and chapter 2) were 134

Table 30. Timber Productivity Statistics - TSHE/BENE-GASH

Species	Site Index[1] (feet) Mean	SD	Current 10-yr. Radial Increment (20ths) Mean	SD	Growth Basal Area[2] (ft^2/ac) Mean	SD	Mean Annual Inc. at Culmination[3] (ft^3/ac/yr) Mean	SD	Current Overstory Vol. Inc.[4] (ft^3/ac/yr) Mean	SD
Douglas-fir	127	21	12	7	381	137	134	30	58	45
Western hemlock	117	16	10	6	330	106	164	31	50	36
Western redcedar	129	8	18	9	1005	332	156	12	48	20

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

ft3/acre-year at culmination of mean annual increment (SDI-based estimate) and 99 ft^3/acre-year as the last decade's ingrowth of the sampled stands. Growth basal area for Douglas-fir was low for the Western Hemlock Zone, reflecting the relative dryness of these sites. The preponderance of leathery-leaved evergreen species also suggests that sites having this association may have lower nutrient availability than other Western Hemlock Zone associations.

Management of this association offers few complications. The relative dryness, the steep slopes and the abundant brush cover are the major concerns. Douglas-fir is the best choice for planting, though on south-facing slopes provisions for some shade are required either through shelterwood harvest, shade cards, or careful harvest unit design. Steep slopes mandate greater care for all activities involving heavy machinery. Brush competition with young conifers may be substantial, including re-growth by brush present in the mature stands or snowbrush ceanothus invasion following slash-burning. Hot slash burns remove valuable shade-providing down logs and can encourage dense snowbrush ceanothus. Thin forest floors are usual so slash burning will cause relatively small nutrient losses.

This association serves important winter range functions. The fairly dense understory of shrubs provides hiding cover as well as forage for big game.

Similar Associations

This association is most similar to the TSHE/GASH, TSHE/BENE, and TSHE/ACTR types described in this paper. The major differences are the low herb cover and the marked abundance of salal and dwarf Oregon grape in combination.

Analogous plant associations are common on all Western Cascade National Forests. Somewhat similar types are found on the Mt. Baker-Snoqualmie (Henderson, personal communication), Mt. Hood (Halverson et al. 1986) and Willamette National Forests (Hemstrom et al. 1985). The Mt. Hood NF version has a different group of associated species, including much more swordfern than is found on the Gifford Pinchot NF. Even the coastal National Forests, the Olympic (Henderson and Peter 1981a) and the Siuslaw (Hemstrom and Logan 1986), contain a similar association, but these also have a different suite of understory species and considerably different timber productive potentials.

TSHE/GASH

CHS1-28

WESTERN HEMLOCK/SALAL

Tsuga heterophylla/Gaultheria shallon

Structure and Composition

Relatively dense thickets of salal with little other vegetation are characteristic of this association. Salal always covers at least 10% of the ground, and cover over 50% is very common. Red huckleberry and dwarf Oregon grape are always present, but only in small amounts. Vine-maple may be present, but plays an unimportant role. Herbs may be present in trace amounts but never cover substantive area. Twinflower and bracken fern are the only species to appear in 50% of the plots. The forest canopy is mostly Douglas-fir and western hemlock, and western redcedar is usually present in small amounts. Western hemlock seedlings generally grow in these stands. Douglas-fir seedlings were present in one-third of our plots, indicating the dryness of this association and the relatively open canopies which result. Appendix 3 presents vegetation data for this association.

Environment and Distribution

Compared to the other western hemlock associations, this one indicates a dry environment because of either (or both) relatively low precipitation or droughty (shallow or stony) soils. Middle and upper slope positions on steep inclines are typical. Any aspect or elevation within the Western Hemlock Zone may have this association, there being a gradual transition into the Pacific Silver Fir/Salal Association which has a similar but colder climate (see Table 2). This association is particularly abundant in Packwood Ranger District, especially in the minor rain-shadow areas just east of major ridges, such as Tatoosh Ridge and the ridge separating the Cispus and Cowlitz drainages (Pompey Peak-Castle Butte). The effectively-dry soils are influenced by the frequent existence of convex topography with some surface rock.

Productivity and Management

The potential producvitity of TSHE/GASH is amongst the lowest of the Western Hemlock Zone associations on the Gifford Pinchot National Forest. Site indices (at 100 years) averaged 117 feet for Douglas-fir and 100 feet for western hemlock. Stocking levels on our plots in this association were high. Complete timber productivity values are presented in Tables 31 and 16 and Appendix 2.

The land manager's primary concern when dealing with this association is the hot environment and effectively dry soils. Removal of the forest cover will accentuate this condition and so provisions are required for protecting planting stock from intense insolation. Shelterwood harvest systems should be considered. Steep slopes are also common and require extra care. Hot slash burns should be discouraged as they remove valuable shade-providing logs and soil-protecting forest floor layers. Snowbrush ceanothus thickets may also follow hot burns. Old-growth stands of this association were not found, suggesting high wildfire potential because of the hot, dry environments. This association is abundant in the low elevation portion of the upper Cowlitz valley, serving as important winter range for the large populations of deer and elk in that region.

Table 31. Timber Productivity Statistics - TSHE/GASH

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	117	17	11	4	317	137	120	24	50	48
Western hemlock	100	24	6	1	291	72	129	47	21	7
Western redcedar	86	12	15	1	437	1	87	19	20	4
Western white pine	100	-	5	-	213	-	188	-	2	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962; Western redcedar, Hegyi et al. 1981. Western white pine, Forest Service Silviculcural Practices Handbook, converted to base age 100.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

Similar Associations

The near absence of herb cover and the shrub-layer dominance of salal are what distinguishes this association from similar types, such as TSHE/BENE-GASH and TSHE/BENE. Drier and hotter associations (TSHE/CONU/ACTR and TSHE-PSME/HODI) have more oceanspray and California hazel. This association is analogous to the higher elevation ABAM/GASH type previously described on the G.P. (Brockway et al. 1983).

Other Western Cascade National Forests also have a very similar association, including the Mt. Baker-Snoqualmie (Henderson and Peter 1981b), Olympic (Henderson and Peter 1981a), Willamette (Hemstrom et al. 1985) and Siuslaw (Hemstrom and Logan 1986). This association appears to be absent from the Mt. Hood N.F. (Halverson et al. 1986), though the very similar Western hemlock/Dwarf Oregon grape-salal Association is widespread. TSHE/GASH is also found in Mt. Rainier National Park (Franklin et al. 1979).

TSHE/CONU/ACTR

CHS2-24

WESTERN HEMLOCK/DOGWOOD/VANILLA-LEAF

Tsuga heterophylla/Cornus nuttallii/Achlys triphylla

Structure and Composition

This association has very high shrub cover which is generally accompanied by several herb species. Vine maple cover is greatest in this association compared to the rest of the Western Hemlock Zone. Pacific dogwood was present on all plots. Other shrubs having substantial cover include dwarf Oregon grape, baldhip rose and creeping snowberry. The herb layer is abundant and diverse. Vanillaleaf has its highest average cover. Other species appear with much lower cover values but have similarly high frequencies: starflower, redwoods violet, trillium, pathfinder, three-leaved anemone and swordfern. Other species which have some of their highest frequencies of occurrence in this association are sweet cicely, sweet-scented bedstraw, fairybells and star-flowered Solomon's seal. See Appendix 3 for a summary of the vegetation of this association.

Regenerating western hemlock were nearly lacking on our plots in this association. The sample plots in this association were in young stands. With time western hemlock will probably invade. Nevertheless, there was more regenerating Douglas-fir than western hemlock, suggesting that this association has affinities with Douglas-fir climax types.

Environment and Distribution

This association represents the hot/dry end of the Western Hemlock Zone on the Gifford Pinchot National Forest. It is largely limited to the southern part of the National Forest, relatively close to the Columbia River. The steep, southern slopes found in the Bear Creek area of the Wind River Ranger District most commonly support this association. It is also found on the south-facing steep slopes above the Lewis River. Randle and Packwood districts probably lack this association. Our study plots were on upper slope positions with elevations of 2600 feet or less and usually have convex microtopography (see Table 2). Deep, relatively stone-free soils derived from breccias were commonly encountered (see Table 4). Plants experience an effectively dry environment because of the intense solar input and the predominate upper slope positions, not because of rocky soils.

This association often borders Oregon white oak woodlands. Its characteristics are indicative of a fairly harsh environment compared with most of the Western Cascades portion of the G.P. This association is limited geographically, but awareness of its presence may greatly help alert the land manager to the special environment.

Productivity and Management

Considering the hot and dry environment where this association exists, it is surprisingly productive. Douglas-fir had an average site index (at 100 years, McArdle) of 135 feet. Growth basal area for Douglas-fir was also quite high (420 ft^2/ac). Tables 32 and 16 and Appendix 2 summarize other timber prodictivity information.

Clearly, this association includes lands which can be valuable commercial forest land once trees become established. The trick is to anticipate the dry conditions which make reforestation difficult. Where possible, the shelterwood system should be considered, as should any type of harvest regime which promotes shade. Clearcut unit design should maximize relative edge per unit area and avoid openings much wider than 2 times the height of adjoining trees. Planting stock should be suited to dry conditions; higher elevation seed should not be used and efforts to obtain on-site seed should be considered. Shade cards and leaving slash will also help create shade. Slash burning should be avoided or limited to cool burns so that surface organic matter is maintained with its insulating properties. Hot burns will be followed by dense snowbrush ceanothus invasion.

Table 32. Timber Productivity Statistics - TSHE/CONU/ACTR

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	135	12	11	5	420	91	145	18	67	38
Western hemlock	129	-	14	-	366	-	186	-	78	-

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961; Western hemlock, Barnes 1962;
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

TSHE/CONU/ACTR includes important winter range. The hot environment stays snow-free for much of the year and there is very high herb and shrub forage availability.

Similar Associations

This association is floristically similar to TSHE/ACTR, but this type has an abundance of Pacific dogwood, has abundant creeping snowberry and nearly lacks bigleaf maple and regenerating western hemlock. TSHE/CONU/ACTR is similar to grand fir/ vanillaleaf associations, but not quite so dry. The Grand Fir/Pacific Dogwood/vanillaleaf Association is found on the Mt. Adams Ranger district can be very similar, especially on the western portions of that district (in the Little White Salmon River drainage) which are transitional to the Western Hemlock Zone.

This association has not been described in any previous plant association classifications. It shares its greatest affinities with the Western Hemlock/Vine-maple/vanillaleaf Associations found on the Mt. Baker-Snoqualmie (Henderson and Peter 1981b) and Mt. Hood National Forests (Halverson et al. 1986). Douglas-fir associations on the Willamette National Forest which include creeping snowberry or oceanspray are somewhat similar but represent even hotter, drier sites (Hemstrom et al. 1985).

TSHE-PSME/HODI — WESTERN HEMLOCK-DOUGLAS-FIR/OCEANSPRAY

CHC2-12 — ***Tsuga heterophylla–Pseudotsuga menziesii/Holodiscus discolor***

Structure and Composition

This association is considered transitional to the Douglas-fir series where Douglas-fir is the dominant climax tree species. (Forest series are defined in the introduction to this paper.) Both western hemlock and Douglas-fir occur in the regeneration layer and can be expected to co-exist in a long term stable condition.

This is a very shrubby association characterized by the presence of dry-site species. These include an abundance of oceanspray, snowberry, baldhip rose and California hazel and lesser amounts of serviceberry and tall Oregon grape. The other abundant shrubs are dwarf Oregon grape and vine-maple. Herbs present are typical of forested Western Cascades dry sites, including various grasses, bigleaf sandwort, starflower, pathfinder and white hawkweed. Swordfern is common but only in small amounts. Less abundant, but more diagnostic of dry sites, are leafy peavine and vetch. See Appendix 3 for a summary of the vegetation found in this association.

Environment and Distribution

Some of the hottest and driest sites in the forested Western Cascades support this association. On the G.P. it is found primarily on the southern part of Wind River Ranger District. It also is found in the rain shadow just east of Tatoosh Ridge in the Ohanapecosh drainage on Packwood Ranger District. On the Mt. Hood National Forest it is found mainly on basalt cliffs above the Clackamas, Salmon and Collawash Rivers and tributaries of the Columbia River. Sites are always upper slopes and fairly steep, where drainage and solar input are excessive (see Table 2). Bare ground and surface rock and gravel are also typical of these dry sites. Soils are shallow and stony, with thin forest floor layers being the rule (see Table 4).

Productivity and Management

Though timber productivity of established stands is reasonable, this association offers considerable management problems and can not be dealt with in the same manner as most areas in the western Cascades. Productivity and stocking indices are lower, but not substantially so, than other Western Hemlock Zone associations. Site index (at 100 years) averaged 113 feet for Douglas-fir (see Tables 33 and 16 and Appendix 2).

Timber planners need to be especially mindful of the silvicultural problems which may result from large openings lacking shade. The shelterwood system should be used whenever possible. If clearcuts are used, shade should be maximized, by both natural and artificial means if necessary. Broadcast burning may lead to considerable snowbrush ceanothus competition with young conifers. Growth of vine-maple, red-flowered currant and sticky currant into disturbed areas may be rapid and present significant competition to tree seedlings for soil moisture. Grasses

Table 33. Timber Productivity Statistics - TSHE-PSME/HODI

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	113	22	12	10	372	158	114	3	65	60

1. McArdle et al. 1961. Indexed to age 100.
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

may also invade disturbed sites in this association so it is wise to avoid any grass seeding projects if conifer establishment is a goal for the site. Douglas-fir is the preferred species for reforestation and every effort should be made to match seed source to site. Plantability will be poor in some cases, so high stocking levels should not be demanded or expected. Soils may dry out quite early in the growing season, making early planting a necessity.

The same hot and dry environmental conditions which make this association challenging to timber management lead to long, snow-free periods. The abundance of suitable shrub species for browse also indicates the high winter range value of this association.

Similar Associations

This association is somewhat similar to the grand fir associations tentatively described for the Mt. Adams Ranger District east of the Cascade crest. These include Grand fir/oceanspray/ vanillaleaf and Grand fir/oceanspray/ grasses.

TSHE-PSME/HODI is somewhat similar to the various other oceanspray types that may exist in either the western hemlock or Douglas-fir series on other western Cascade National Forests. On the Willamette National Forest, Douglas-fir series associations become much more abundant and include types like this, but with more extreme environments (Hemstrom et al. 1985).

TSHE-PSME-ARME

CHC2-13

WESTERN HEMLOCK-DOUGLAS-FIR-MADRONE

Tsuga heterophylla-Pseudotsuga menziesii-Arbutus menziesii

Structure and Composition

This grouping is a product of very steep, rocky and dry slopes. It is very localized, but the distinctive management problems which it presents make it noteworthy. On the Gifford Pinchot National Forest this type is present in only very small amounts. Shrub and herb species include primarily dry-site indicators, including salal, California hazel, dwarf Oregon grape, oceanspray, starflower and grasses. Terrestrial lichen cover (including nitrogen-fixing Peltigera species) can match that of the vascular plant understory. The canopy includes considerable madrone and a predominance of Douglas-fir. Western hemlock is in low abundance. Vegetation data for this association are summarized in Appendix 3.

Environment and Distribution

The very steep and rocky upper slopes and ridges above the Cowlitz River on the Packwood Ranger Distict appear to contain most of the area on the G.P. having this type. The effective environment for plants is very dry because of the lack of rooting medium. Soils are shallow and rocky; rock-outcrops occupy much of the terrain. The rainshadow effect of the major ridges west of Packwood contribute to the dryness of these sites (see Tabales 2 and 4).

Productivity and Management

The productivity of the two plots sampled in this grouping was much lower than that found in the other Western Hemlock Zone associations, but was nevertheless substantial. Site index for Douglas-fir averaged 105 feet (see Tables 33 and 16 and Appendix 2).

Productive potential is likely related to the depth of soils, and this varies over rather small areas. Managers need to be concerned about the substantial problems which can result from logging these sites. The steep slopes may be very prone to failure and the lack of soil leads to very difficult reforestation. Because of the patchy nature of these sites it seems that these locales should be avoided when designing timber sale boundaries. Plantation re-establishment in 5 years can not be expected. Scenic and other values are high and are likely the most appropriate use of these rocky sites.

Similar Associations

This grouping has not been formally recognized in previous plant association descriptions for the Western Cascades. The widspread madrone communities in the rain shadow areas on the northeast portion of the Olympic Peninsula, Vancouver Island and environs are quite different from this association on the Gifford Pinchot National Forest.

Table 34. Timber Productivity Statistics - TSHE-PSME-ARME

Species	Site Index[1] (feet)		Current 10-yr. Radial Increment (20ths)		Growth Basal Area[2] (ft^2/ac)		Mean Annual Inc. at Culmination[3] (ft^3/ac/yr)		Current Overstory Vol. Inc.[4] (ft^3/ac/yr)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Douglas-fir	105	13	13	10	385	203	103	18	15	1

1. Indexed to age 100. References: Douglas-fir, McArdle et al. 1961;
2. Hall 1983.
3. See discussion of Timber Productivity in Chapter 2 for references.
4. Methods after Hemstrom 1983.

LITERATURE CITED

Barnes, G.H. 1962. Yield of even-aged stands of western hemlock. USDA Tech. Bull. No. 1273. 52 pp.

Bartels, R., J.D. Dell, R.L. Knight and G. Shaefer. 1985. Dead and down woody material. Ch. 8 In: Brown, E.R. (tech. ed.), Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington. USDA Forest Service, Pacific Northwest Region, R6-F&WL-192-1985.

Becking, R.W. 1954. Site indicators and forest types of the Douglas-fir region of western Washington and Oregon. Ph.D. thesis, College of Forestry, Univ. of Wash., Seattle.

Brockway, D.G., C. Topik, M.A. Hemstrom and W.H. Emmingham. 1983. Plant association and management guide for the Pacific silver fir zone, Gifford Pinchot National Forest. USDA Forest Service Area Guide, R6-ECOL-130a-1983. Pacific Northwest Region. Portland, Oregon.

Brown, J.K. 1974. Handbook for inventorying downed woody material. USDA Forest Service Gen. Tech. Rep. INT-16. Intermountain Forest and Range Experiment Station, Ogden Utah.

Cline, S.P., A.B. Berg and H.M. Wight. 1980. Snag characteristics and dynamics in Douglas-fir forests, western Oregon. J. Wildl. Management 44:773-786.

Crouch, G.L. 1981. Coniferous forest habitats. Food habits and nutrition. Chapter 11, part 1 IN O.C. Wallmo ed., Mule and Black-tailed Deer of North America. Univ. of Nebraska Press, Lincoln.

Cochran, P.H. 1979. Site index and height growth curves for managed, even-aged stands of white or grand fir east of the Cascades in Oregon and Washington. USDA Forest Service Res. Pap. PNW-252, 13 p. PNW For. and Range Experiment Station, Portland, OR.

Dawson, M.D., E.G. Knox and F.W. Gelderman. 1972. A Guide to Soil Classification. Oregon State Univ. Bookstore Press, Corvallis, Or

Deeming, J.E., R.E. Burgan and J.D. Cohen. 1977. The National Fire-danger rating system - 1978. USDA Forest Service Gen Tech. Rep. INT-39. Intermountain Forest and Range Experiment Station, Ogden Utah.

Driscoll, R.S., D.L. Merkel, D.L. Radloff, P.E. Snyder and S. James. 1984. An ecological land classification framework for the United States. Misc. Pub. 1439. Washington D.C. USDA. 56 pp.

Dyrness, C.T., J.F. Franklin and W.H. Moir. 1974. A preliminary classification of forest communities in the central portion of the Western Cascades of Oregon. US/IBP coniferous Forest Biome Bull. No. 4, Univ. Wash.

Franklin, J.F. and F.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. USDA-Forest Service General Tech. Rep. PNW-8. Pac. NW Forest and Range Expt. Station. Portland, OR 417pp.

Franklin, J.F., W.H. Moir, M.A. Hemstrom, and S. Greene. 1979. Forest ecosystems of Mount Rainier National Park. Unpublished manuscript. Forestry Sciences Laboratory, Oregon State University, Corvallis, OR 221 pp.

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. USDA Forest Service Gen. Tech. Rep. PNW-118. Pacific Northwest Forest and Range Experiment Station, Portland Oregon.

Garrison, G.A., J.M. Skovlin, C.E. Poulton, and A.H. Winward. 1976. Northwest plant names and symbols for ecosystem inventory and analysis. Fourth edition. USDA Forest Service Gen. Tech. Report PNW-46. Pacific NW Forest and Range Expt. Station. Portland, OR 263 pp.

Gauch, H.G. Jr. 1977. Ordiflex. A flexible computer program for four ordination technique. (plus amendments) Ecology and Systematics, Cornell University, Ithaca, New York.

Gauch, H.G. Jr. 1982. Multivariate Analysis in Community Ecology. Cambridge University Press, New York. 298 pp.

Gifford Pinchot National Forest. 1986. Proposed Forest-wide standard/guidelines and management strategies. Vancouver WA.

Greene, S.E. and M.Klopsch. 1985. Soil and air temperatures for different habitats in Mount Rainier National Park. USDA Forest Service Res. Paper PNW-342. Pacific Northwest Foest and Range Expt. Station, Portland Or.

Hall, F.C. 1983. Growth basal area: a field method for appraising forest site potential for stockability. Can. J. For. Res. 13: 70-77.

Hall, F.C. 1984. Ecoclass coding system for Pacific Northwest plant associations. USDA Foerst Service, Pacific Northwest Region R6-ECOL-173-1984.

Hall, F.C. 1985. Growth Basal Area handbook. USDA Forest Service, Pacific Northwest Region, R6-ECOL-181b-1984.

Halverson, N.M., R. Lesher, D. McClure, J. Riley, C. Topik and A. Rodahorst. 1986. Major indicator shrubs and herbs on National forests of western Oregon and southwest Washington. USDA Forest Service, Pacific Northwest Region, R6-TM-229-1986.

Halverson, N. M., C. Topik and R. van Vickle. 1986. Plant association and management guide for the Western Hemlock Zone, Mt. Hood National Forest. USDA Forest Service, Pacific Northwest Region, Portland, OR, R6-ECOL-232a-1986.

Hammond, P. E. 1980. Reconnaissance geologic map and cross sections of southern Washington Cascade Range. Dept. of Earth Sci. Portland State Univ.

Hanley, T.A. 1984. Relationship between sitka black-tailed deer and their habitat. Gen. Tech. Rep. PNW-168. USDA Forest Service, Pacific Northwest Forest and Range Expt. Station, Portland Or.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, Jr., and K.W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15:133-302.

Hegyi, F., J.J. Jelnick, J. Visgai, and D.B. Carpenter. 1981. Site index equations for the major tree species in British Columbia. Ministry of Forests, Inventory Branch. Victoria, B.C. Canada

Hemstrom, M.A. 1983. unpublished paper on file at Willamette National Forest, Eugene, Or on high elevation tree growth simulator.

Hemstrom, M.A. and S.E. Logan. 1986. Plant association and management guide, Siuslaw National Forest. USDA Forest Service Area Guide, R6-ECOL-220-1986a Pacific Northwest Region, Portland OR.

Hemstrom, M.A., S. E. Logan and W. Pavlat. 1985. Preliminary plant association and management guide, Willamette National Forest. Report on file at Willamette NF, Eugene, OR.

Henderson, J.A. and D. Peter. 1981a. Preliminary plant associations and habitat types of the Shelton Ranger District, Olympic National Forest. USDA Forest Service, Olympic National Forest. Olympia, WA

Henderson, J.A. and D. Peter. 1981b. Preliminary plant associations and habitat types of the White River District, Mt. Baker-Snoqualmie National Forest. USDA Forest Service, Olympic NF, Olympia, WA

Herman, F.R., R.O. Curtis and D.J. DeMars. 1978. Height growth and site index estimates for noble fir in high elevation forests of the Oregon and Washington Cascades. USDA Forest Service Res. Paper PNW-243. Pacific Northwest Forest and Range Expt. Station, Portland, OR.

Hogfoss, Bob. 1985. Fire history of the Gifford Pinchot National Forest. unpublished manuscript on file at Mt. St. Helens National Volcanic Monument.

Jenny, H. 1980. The Soil Resource, Origin and Behavior. Springer Verlag. New York. 377 pgs.

Johnson, D.M. and J.O. Dart. 1982. Variability of precipitation in the Pacific Northwest: spatial and temporal characteristics. Completion report for Project A-050-ORE, Office of Water Research and Technology, U.S. Dept. Interior.

King, J.E. 1966. Site index curves for Douglas-fir in the Pacific Northwest. Weyerhaeuser Forestry Paper No. 8. Centralia, WA

Klinka, K., M.C. Feller, and L.E. Lowe. 1981. Characterization of the most productive ecosystems for growth of *Pseudotsuga menziesii* var. *menziesii* in southwestern British Columbia. Ministry of Forests, Province of British Columbia.

Klinka, K., R.N. Green, R.L. Trowbridge and L.E. Lowe. 1981. Taxonomic classification of humus forms in ecosystems of British Columbia. First Approx. Land Man. Rep. # 8, Prov. of B. C. Ministry of Forests. Victoria, B.C.

Lassoie, J.P. 1982. Physiological activity in Douglas-fir. In: Analysis of Coniferous Forest Ecosystems in the Western United States; ed. R.L. Edmonds. Hutchinson Ross Pub. Co., Stroudsburg, Penn.

Lowe, L.E. and K. Klinka. 1981. Forest humus in the Coastal Western Hemlock Biogeoclimatic Zone of Britist Columbia in relation to forest productivity and pedogenesis. Research Note # 89. Prov. of B. C. Victoria, B. C.

McArdle, R.E., W.H. Meyer and D. Bruce. 1930. rev. 1949. The yield of Douglas-fir in the Pacific Northwest. USDA Tech. Bull. No. 201.

Maser, C., R.G. Anderson, K. Cromack, Jr., J.T. Williams and R.E. Martin. 1979. Dead and down woody material. Ch. 6 IN: Thomas, J.W. (tech ed.), Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handbook 553. Washington D.C.: USDA.

Maser. C. and J.M. Trappe (tech eds.) 1984. The seen and unseen world of the fallen tree. USDA Forest Service Gen. Tech. Rep. PNW-164. Pacific Northwest Forest and Range Experiment Station, Portland Oregon.

Maxwell, W.G. and F. R. Ward. 1980. Photo series for quantifying natural forest residues in common vegetation types of the Pacific Northwest. USDA Forst Service Gen. Tech. Rep. PNW-105. Pacific Northwest Forest and Range Experiment Station, Portland Oregon.

Neitro, W.A., V.W. Binkley, S.P. Cline, R.W. Mannan, B.G. Marcot, D. Taylor, and F.F. Wagner. 1985. Snags (Wildlife trees). Ch. 7 In: Brown, E.R. (tech. ed.), Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington. USDA Forest Service, Pacific Northwest Region, R6-F&WL-192-1985.

Pfister, R.D., B.L. Kovelchik, S.F. Armo, and R.C. Presby. 1977. Forest habitat types of Montana. USDA For. Serv. Gen. Tech. Rep. INT-34, 174 pp. Intermountain For. and Range Expt. Station. Ogden, UT

Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. J. Agric. Res. 46:627-638.

Schmidt, W.C., R.C. Shearer and A.L. Roe. 1976. Ecology and Silviculture of western larch forests. USDA Tech. Bull. No. 1520. Intermountain Forest and Range Expt. Station. Ogden, UT

Smith, J.H.G. 1968. Growth and yield of red alder in British Columbia. In: Biology of Alder, Pacific Northwest For. and Range Expt. Station, Portland, OR pp 273-286

Sondheim, M.W. and K. Klinka. 1983. The relationship of soil and physiographic attributes to an ecological classification system. Can. J. Soil Sci. 63:97-112.

Swanson, F.J. 1979. Geomorphology and Ecosystems. p159-170. IN: Forests: Fresh Perspectives from Ecosystem Analysis. ed. R. H. Waring. Oreg. St. Univ. Press, Corvallis Or.

Tepley, J. 1985. equations used by forest inventory for estimating yield capacity at culmination of mean annual increment. personal communication.

U.S. Weather Bureau. 1965. Annual precipitation for the State of Washington from 1930 to 1957. U.S. Dept. of Commerce and U.S.D.A. Portland, OR.

Volland, L.A. and M. Connelly. 1978. Computer analysis of ecological data: methods and programs. USDA Forest Service. Pac. NW Region. Pub. No. R6-ECOL-79-003. Portland, OR 382 pp.

Walker, G. W. and A. B. Griggs. 1979. The Cascade Range in Oregon and Southern Washington. p23-29. IN: Forest Soils of the Douglas-fir Region. ed by P.E. Heilman, H.W. Anderson and D. M. Baumgartner. Wash. St. Univ. Coop. Ext. Service, Pullman, Wash.

Wise, W.S. 1970. Cenozoic volcanism in the Cascade Mountains of Southern Washington. Wash. St. Dept. of Nat. Res. Div. of Mines and Geol. Bull. 60

Worthington, N.P., F.P. Johnson, G.R. Staebler and W.J. Lloyd. 1960. Normal yield tables for red alder. Research Paper 36. USDA Forest Service, Pacific Northwest Forest and Range Expt. Station, Portland Or.

APPENDICES

APPENDIX 1

Locations of Gifford Pinchot NF Western Hemlock Zone study plots. Percent of study plots of each association by Ranger Districts and mapping units Range and Township.

	TSHE/ LYAM	TSHE/ ATFI	TSHE/ OPHO/ POMU	TSHE/ VAAL/ OXOR	TSHE/ POMU-OXOR	TSHE/ TITR
Ranger Districts						
Mt. St. Helens N.V.M.		38	6	50	7	46
Mt. Adams			6			
Packwood		38	12			19
Randle	100	13	65	50	71	19
Wind River		13	12		21	15
Mapping Range East, Willamette Meridian						
4				100	23	19
5			6		46	15
6			6		15	38
7		71	38		15	
7.5			6			8
8		14	31			15
9	100	14	13			4
10						
Mapping Township North, Willamette Meridian						
3						
4			6			8
5			6		23	4
6						4
7			13		8	35
8		43				12
9						
10	100	14				4
11			50		46	12
12		14	13			4
13			6			4
14		14		100	14	12
15		14	6			4

Appendix 1 continued

	TSHE/ POMU	TSHE/ BENE/ POMU	TSHE/ VAAL/ COCA	TSHE/ VAAL-GASH	TSHE/ ACTR	TSHE/ BENE
Ranger Districts						
Mt. St. Helens N.V.M.	6	13	23	13	15	6
Mt. Adams	6					3
Packwood	6	6	8	13	23	26
Randle	56	44	38	13	25	66
Wind River	25	38	31	63	38	
Mapping Range East, Willamette Meridian						
4	6		9	13	1	6
5	6	13		25	1	
6			18	13	7	
7	69	33	36	50	40	19
7.5		7			1	
8	6	33	36		26	39
9	13	13			12	35
10					11	
Mapping Township North, Willamette Meridian						
3	6	13			4	
4	19	13	9	50	24	
5		13	27	13	6	
6			9		2	
7	13	7			10	3
8		7		13	7	3
9						
10		33	9		3	16
11	19	7			19	39
12	25				7	10
13	13		27		8	10
14		7	9	13	10	13
15	6		9	13		6

Appendix 1 continued

	TSHE/ BENE-GASH	TSHE/ GASH	TSHE/ CONU/ ACTR	TSHE-PSME/ HODI	TSHE-PSME-ARME
Ranger Districts					
Mt. St. Helens N.V.M.	12	10	10		
Mt. Adams			10		
Packwood	43	60			100
Randle	26	25		13	
Wind River	19	5	80	87	
Mapping Range East, Willamette Meridian					
4	8	5			
5					
6	3		11		
7	11	21	22		
7.5			11	14	
8	3	16	56	71	
9	34	42		14	
10	16	16			100
Mapping Township North, Willamette Meridian					
3			11	14	
4	16	5	78	71	
5					
6					
7	5	16	11		
8	11				
9					
10	8	5		14	
11	8	5			
12	11	26			
13	26	5			
14	11	32			100
15	5	5			

APPENDIX 2

Timber productivity indices of individual tree species, listed by plant association.

The values listed are the means (and standard deviations in parentheses) of plot averages per association.

Associations are listed in order approximating a moist to dry gradient.

The variables listed are:

current growth: the radial increment of the most recent 10 years growth, in 1/20 inch. (= 1/10 inch diameter growth)
GBA: growth basal area, the basal area at which a stand would be expected to grow at 10/20 inch radial increment per decade at stand age 100 (Hall 1983)
total volume: the volume in cubic feet per acre of that species
age: age at breast height
yield capacity: an approximate index of the anticipated volume productivity of such a stand at culmination of mean annual increment (Tepley 1985)
crown ratio: the per cent of tree bole having foliar crown
site index: base age 100, the expected height of dominant trees at age 100.

code	tree species	site index reference
PSME	Douglas-fir	McArdle et al. 1949: uses total age
TSHE	western hemlock	Barnes 1962: uses total age
THPL	western redcedar	Hegli et al. 1981, converted to feet uses age at breast height
ALRU	red alder (base age 50)	Worthington et al. 1960: uses age at breast height plus 2 years
ACMA	big-leaf maple (base age 50)	Worthington et al. 1960: site index table for red alder
ABPR	noble fir	Herman et al. 1978: uses age BH
ABAM	Pacific silver fir	Hegli et al. 1981, converted to feet uses age at breast height
POTR2	cottonwood	Hegli et al. 1981, converted to feet uses age at breast height
LAOC	western larch	Schmidt et al. 1976: converted to base age 100: uses total age
ABGR	grand fir	Cochran 1979: uses breast height age
PIMO	western white pine	Forest Service Silvicultural Practices Handbook: uses total age

Appendix 2.

ASSOCIATION	SPECIES	# PLOTS	# TREES	SITE INDEX (100)	CUR. GRTH. (1/20")	GBA ft^2/ac	TOTAL VOLUME ft^3/ac	AGE	YIELD CAPACITY ft^3/ac/yr	CROWN RATIO %
TSHE/LYAM	THPL	1	3	102	27	812	3629	104	113	68
TSHE/ATFI	PSME	7	29	166	19	601	5424	135	190	36
				(19)	(9)	(224)	(2897)	(105)	(27)	(8)
	TSHE	1	5	124	12	350	5359	93	177	53
	THPL	1	5	153	8	477	9576	337	195	50
	ALRU	1	3	110*	27	673	2664	70	135	32
TSHE/OPHO/POMU	PSME	14	65	172	15	556	6696	244	198	38
				(21)	(7)	(133)	(3912)	(225)	(29)	(7)
	TSHE	7	28	126	16	579	4855	142	180	41
				(5)	(9)	(384)	(1781)	(49)	(9)	(7)
	THPL	1	5	134	11	532	6108	302	164	39
TSHE/POMU-OXOR	PSME	45	216	157	14	463	6453	179	176	36
				(18)	(5)	(127)	(3132)	(162)	(26)	(9)
	TSHE	24	99	145	18	527	4844	103	218	46
				(18)	(6)	(199)	(2569)	(59)	(35)	(11)
	THPL	3	12	141	28	706	5500	172	170	56
				(7)	(10)	(119)	(2050)	(24)	(10)	(3)
	ACMA	1	5	66	17	623	2855	66	60	16
TSHE/VAAL/OXOR	ABPR	2	6	134	22	564	1411	65	164	34
				(34)	(17)	(263)	(1891)	(35)	(54)	(2)
	PSME	12	57	136	15	437	4023	147	204	38
				(13)	(6)	(114)	(2922)	(18)	(267)	(8)
	TSHE	9	42	121	14	444	4617	124	170	47
				(17)	(5)	(104)	(2691)	(72)	(32)	(10)
	THPL	2	10	95	15	404	1349	56		47
				(5)	(.7)	(84)	(754)	(18)		(6)
TSHE/TITR	PSME	25	114	163	13	564	7263	236	185	35
				(15)	(6)	(157)	(3964)	(169)	(21)	(13)
	TSHE	9	38	127	14	564	5465	128	182	49
				(17)	(6)	(221)	(2600)	(21)	(34)	(10)
	THPL	4	14	135	13	694	5756	279	165	56
				(28)	(3)	(318)	(4605)	(102)	(44)	(15)
TSHE/POMU	PSME	16	70	161	14	504	6645	192	182	33
				(22)	(6)	(161)	(4186)	(171)	(30)	(11)
	TSHE	6	23	137	13	431	3912	164	202	40
				(19)	(5)	(169)	(1574)	(96)	(37)	(22)
	THPL	2	4	125	25	936	2586	205	150	61
				(30)	(12)	(606)	(160)	(48)	(47)	(13)
TSHE/BENE/POMU	PSME	26	114	142	12	401	5458	193	155	34
				(18)	(5)	(120)	(3257)	(140)	(25)	(10)
	TSHE	7	23	128	12	380	3967	154	184	47
				(15)	(5)	(152)	(1350)	(88)	(29)	(12)
	THPL	3	7	98	(10)	381	3272	310	105	41
				(17)	(5)	(75)	(1165)	(198)	(38)	(18)

* site index for ALRU and ACMA are base age 50.

Appendix 2. continued

ASSOCIATION	SPECIES	# PLOTS	# TREES	SITE INDEX (100)	CUR. GRTH. (1/20")	GBA ft^2/ac	TOTAL VOLUME ft^3/ac	AGE	YIELD CAPACITY ft^3/ac/yr	CROWN RATIO %
TSHE/VAAL/COCA	ABPR	1	1	131	5	347	717	311	160	35
	LAOC	1	3	104	2	243	508	206		37
	PSME	13	52	135	8	349	4250	465	146	39
				(22)	(9)	(113)	(3105)	(293)	(31)	(17)
	TSHE	15	63	125	9	375	5223	290	178	43
				(24)	(4)	(153)	(2425)	(140)	(47)	(16)
	THPL	1	5	126	9	487	5049	405	152	64
TSHE/VAAL-GASH	ABAM	1	3	142	6	189	1325	184	177	45
	ABPR	1	3	159	20	395	1902	54	204	67
	PSME	6	23	123	8	396	5212	308	129	29
				(23)	(5)	(116)	(2658)	(208)	(33)	(24)
	TSHE	8	31	117	7	295	7088	279	164	29
				(19)	(2)	(120)	(4164)	(46)	(37)	(26)
	THPL	2	3	102	8	277	1313	198	113	58
				(13)	(5)	(73)	(663)	(29)	(20)	(18)
TSHE/ACTR	ABGR	3	7	122	13	431	3230	119	127	43
				(34)	(10)	(208)	(1751)	(49)	(48)	(7)
	ABPR	1	3	160	29	891	866	48	206	48
	ACMA	1	3	87*	21	488	2392	76	96	33
	ALRU	1	5	77*	10	291	1811	51	79	18
	PIMO	1	1	150	18	500	782	508		45
	POTR2	2	8	165	24	723	1763	92	228	31
				(20)	(5)	(30)	(2493)	(38)	(35)	(16)
	PSME	124	599	139	12	402	6811	173	152	32
				(21)	(6)	(136)	(3792)	(125)	(30)	(14)
	TSHE	28	96	120	12	416	3825	181	169	47
				(19)	(5)	(156)	(1796)	(85)	(38)	(19)
	THPL	6	20	116	13	505	4181	234	143	49
				(27)	(4)	(221)	(3376)	(110)	(53)	(25)
TSHE/BENE	PSME	39	187	125	10	380	5198	191	131	34
				(21)	(6)	(116)	(3231)	(146)	(30)	(8)
	TSHE	23	93	118	12	424	4497	171	166	43
				(18)	(3)	(200)	(2626)	(90)	(36)	(12)
	THPL	4	17	124	9	455	6648	216	154	44
				(15)	(3)	(43)	(3061)	(18)	(25)	(12)
TSHE/BENE-GASH	PSME	37	174	127	12	381	6040	181	134	31
				(21)	(7)	(137)	(3024)	(154)	(30)	(17)
	TSHE	10	44	117	10	330	5623	194	164	40
				(16)	(6)	(106)	(2876)	(101)	(31)	(19)
	THPL	2	7	129	18	1005	4292	268	156	46
				(8)	(9)	(332)	(581)	(139)	(12)	(9)
TSHE/GASH	PSME	19	94	117	11	317	4344	147	120	36
				(17)	(4)	(137)	(2986)	(124)	(24)	(13)
	TSHE	5	22	100	6	291	2812	146	129	29
				(24)	(1)	(72)	(1359)	(46)	(47)	(17)
	THPL	2	6	86	15	437	1316	118	87	30
				(12)	(1)	(1)	(664)	(32)	(19)	(42)
	PIMO	1	1	100	5	213	236	159	188	40
TSHE/CONU/ACTR	PSME	9	41	135	11	420	8972	178	145	20
				(12)	(5)	(91)	(3580)	(115)	(17)	(20)
	TSHE	1	5	129	14	366	8041	165	186	
TSHE-PSME/HODI	PSME	11	55	113	12	372	6471	145	114	27
				(22)	(9)	(158)	(3361)	(81)	(32)	(21)
TSHE-PSME-ARME	PSME	2	10	105	9	385	3560	279	103	40
				(13)	(3)	(203)	(357)	(59)	(18)	(11)

* site index for ALRU and ACMA are base age 50.

APPENDIX 3

Mean percent cover and constancy of plant species in Western Hemlock Zone plant associations.

%COV is the average percent cover of a species for those plots on which it occurs.

CONS constancy = the percent of the total plots in an association on which a species is present.

See Table 17 (or Garrison et al. 1976) for definitions of species codes.

The order of the associations in this appendix is:

TSHE/LYAM
TSHE/VAAL/OXOR
TSHE/POMU-OXOR
TSHE/BENE/POMU
TSHE/VAAL/COCA
TSHE/ACTR
TSHE/VAAL/GASH
TSHE/BENE
TSHE-PSME/HODI

(Note: data from the Gifford Pinchot and Mt. Hood National Forests were combined for these associations)

TSHE/ATFI
TSHE/OPHO/POMU
TSHE/POMU
TSHE/TITR
TSHE/BENE-GASH
TSHE/GASH
TSHE/CONU/ACTR
TSHE-PSME-ARME

(Note: data for these associations are all from the Gifford Pinchot National Forest)

	TSHE/LYAM		TSHE VAAL/OXOR		TSHE POMU-OXOR		TSHE BENE/POMU		TSHE VAAL/COCA	
#PLOTS	5		24		82		33		27	
# ON GP	1		2		14		16		13	
# ON MH	4		22		68		17		14	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
MATURE TREES										
ABAM			3.7	13	5.0	1	5.5	6	2.8	33
ABGR	30.0	20			15.0	2				
ABPR			15.0	4	5.0	1			3.5	7
ACMA	30.0	20	1.0	4	8.0	23	8.8	58		
ALRU	32.0	80	15.0	4	8.6	6	2.0	3	10.0	4
PIMO									1.0	4
POTR2										
PSME	22.3	60	35.8	100	48.3	100	46.5	100	28.5	96
TABR			1.5	8	1.8	6	18.0	12	5.9	26
THPL	31.8	80	16.4	46	17.7	55	14.3	48	18.1	70
TSHE	30.0	40	43.3	100	36.9	95	27.4	76	46.0	96
REGENERATING TREES										
ABAM			2.8	38	1.0	1	1.0	6	2.2	41
ABGR	1.0	20			1.0	2	4.0	6		
ACMA					1.1	9	2.0	18		
ALRU	2.0	20			1.0	2				
PSME			1.0	4	1.0	1	1.0	3	4.0	11
THPL	1.3	80	4.4	33	2.2	30	2.1	27	3.4	48
TSHE	1.0	20	17.5	8	9.5	17	7.5	45	8.1	44
SHRUBS										
ACCI	30.6	100	12.8	54	14.8	73	23.9	94	12.4	63
ACGLD									2.0	4
AMAL					1.0	1	1.5	6	1.0	7
BEAQ							1.0	3		
BENE	2.0	20	3.8	67	11.0	82	21.8	100	9.3	89
CACH									1.0	11
CHUM			1.0	4			1.2	18	3.0	56
COCO2	1.0	20	4.0	4	2.0	7	6.2	36	1.0	7
CONU			5.0	4	2.0	1	3.5	24		
GASH			12.3	46	6.8	54	3.6	61	2.7	48
HODI					2.0	5	2.5	12		
MEFE			1.0	13	1.5	5	1.0	3	2.3	15
OPHO	5.0	20	1.5	33	1.6	21	1.4	15	1.3	11
RHDI										
RHMA			1.0	13	5.9	18	1.0	3	5.1	33
ROGY					1.4	9	2.4	27	2.4	26
RUNI			2.0	13	1.0	10	1.3	12	1.0	15
RUPA	2.5	40	1.0	4	1.8	5	1.0	15		
RUSP	2.5	40	1.0	13	1.0	4	1.0	3	1.0	4
SYAL					1.5	2	1.3	12		
SYMO			1.0	4	1.2	6	1.7	18	1.5	15
VAAL	2.0	20	22.9	100	2.3	18	1.5	12	17.5	96
VAME			2.0	8	7.3	4			4.1	52
VAOV			1.0	4	2.0	2			7.9	37
VAPA	1.0	40	8.5	79	3.8	88	3.1	70	5.3	78

Appendix 3 (cont.)

	TSHE/LYAM		TSHE/ VAAL/OXOR		TSHE POMU-OXOR		TSHE BENE/POMU		TSHE VAAL/COCA	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
HERBS										
ACTR			3.7	29	3.5	24	2.6	67	2.8	44
ADBI	1.0	40			1.6	15	2.1	39	1.0	4
ADPE					2.1	15	1.6	15		
ANDE			1.4	21	1.4	22	1.7	52	1.4	19
ARMA3							1.2	15		
ASCA3	2.0	80	2.5	8	1.2	12	1.7	9	4.5	7
ATFI	15.2	100	1.8	21	2.2	32	1.2	15	2.0	4
BLSP			3.3	75	2.3	39	3.5	6	1.5	15
CASC2					2.0	4	1.5	12		
CLUN	1.0	40	1.8	50	1.4	16	1.6	21	2.4	59
COCA	2.0	20	5.2	79	2.4	12	1.5	6	8.2	100
DIFO	1.0	40	1.5	8	2.1	17				
DIHO			1.6	29	1.5	41	1.1	21	1.0	15
DRAU2	2.0	60	1.7	25	2.1	29	1.0	3		
FESU	1.0	40			1.0	5	2.5	6		
GATR	1.0	60	1.0	8	1.3	34	1.6	42	1.0	7
GOOB			1.0	8	1.8	5	1.4	42	1.0	41
GYDR					1.3	4	2.5	6	1.0	4
HIAL					1.3	5	1.2	18	1.0	4
HYTE					1.0	3				
LAPO							1.0	3		
LIBO2	2.0	40	3.2	63	2.6	20	2.4	36	7.7	93
LYAM	27.2	100			2.5	2				
MADI2	1.3	60	3.1	33	1.6	26	2.0	6	3.5	15
MOSI	2.7	60	1.0	4	1.4	12	1.0	12	1.0	4
NEPA										
OSCH					1.5	2	5.7	9		
OSPU	1.0	20			1.0	1			1.0	4
OXOR	2.7	60	26.6	100	44.9	100	5.0	3	5.0	4
POMU	7.0	80	3.3	92	18.8	100	25.5	100	2.1	41
PTAQ	5.0	20	1.7	13	3.5	40	2.3	36	4.7	26
PYSE									1.0	15
SMRA					1.3	15	1.2	27	1.0	11
SMST	3.0	20	6.7	50	2.8	33	1.4	36	3.9	37
SYRE							2.5	6		
TITR	16.0	60	1.7	75	1.8	38	1.9	36	3.4	56
TOME	14.0	60			2.0	1	1.0	3	1.0	4
TRLA2			1.0	8	1.3	13	2.2	52	1.0	4
VAHE	2.0	20	5.7	25	2.2	37	1.9	52	2.7	41
VIOR2					1.8	5	1.6	21	2.0	11
VISE			1.5	25	1.5	33	2.6	21	1.4	30
XETE			1.0	4	1.0	4			9.2	33
MOSS	37.4	100	21.6	100	28.3	96	38.9	100	42.3	100
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS

Appendix 3 (cont.)

	TSHE/ACTR		TSHE VAAL-GASH		TSHE/BENE		TSHE-PSME/HODI	
# PLOTS	141		17		64		36	
# ON GP	94		8		35		8	
# ON MH	47		9		29		28	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
MATURE TREES								
ABAM	3.1	5	2.2	29	2.7	9	1.0	6
ABGR	14.8	9			17.5	3		
ABPR	7.5	3	5.5	12	1.3	5		
ACMA	4.7	22			2.5	9	15.2	44
ALRU	5.5	9			2.0	2		
PIMO	2.0	1	1.0	6	3.3	5	1.0	3
POTR2	20.0	1						
PSME	49.5	100	28.9	88	36.9	97	65.8	100
TABR	5.2	9	1.0	6	6.4	22	2.5	6
THPL	13.7	36	7.4	65	9.3	58	8.5	11
TSHE	24.6	66	39.1	100	39.9	88	17.8	28
REGENERATING TREES								
ABAM	1.5	12	4.3	35	1.2	16		
ABGR	2.5	12	10.0	6	2.0	5	1.0	3
ACMA	1.4	13			3.0	2	1.5	6
ALRU	1.2	4			1.0	2		
PSME	1.6	12	1.0	18	1.8	14	2.0	28
THPL	2.6	23	2.3	41	2.6	36	2.2	14
TSHE	3.7	50	4.0	47	3.6	42	2.7	8
SHRUBS								
ACCI	17.2	90	21.2	59	9.6	84	21.7	86
ACGLD	1.8	4			2.0	3	6.3	33
AMAL	1.5	8			1.0	3	1.8	53
BEAQ	0	0			2.0	3	1.7	31
BENE	15.7	97	5.2	76	13.9	94	22.0	86
CACH	7.5	4	2.0	6	2.1	11	2.2	17
CHUM	3.1	33	3.0	41	2.1	44	1.8	14
COCO2	2.3	30			2.2	9	4.2	72
CONU	2.4	26	2.0	6	1.7	5	2.0	14
GASH	5.4	42	14.2	100	1.6	44	3.0	19
HODI	1.7	7					7.6	83
MEFE	1.0	1	1.5	12				
OPHO	1.2	8					1.0	3
RHDI	0	0					2.3	8
RHMA	2.1	8	1.8	24	1.9	14	3.7	8
ROGY	2.3	51	2.0	18	1.8	13	5.8	22
RUNI	1.7	11			1.1	11		
RUPA	1.6	19	2.0	6	1.0	2	4.1	22
RUSP	1.1	8	2.0	6	1.0	3	1.0	3
SYAL	1.5	4					7.3	17
SYMO	2.2	42	10.0	6	1.2	23	5.4	67
VAAL	2.3	10	12.9	94	1.5	3	2.0	3
VAME	1.1	16	5.3	18	1.3	13	2.5	6
VAOV	1.7	7	9.3	18	1.0	5	1.0	3
VAPA	2.2	61	6.2	88	1.4	64	1.9	28

Appendix 3 (cont.)

	TSHE/ACTR		TSHE VAAL-GASH		TSHE/BENE		TSHE-PSME/HODI	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
HERBS								
ACTR	6.8	92	2.3	18	1.3	42	3.2	42
ADBI	2.3	46			1.0	14	3.0	50
ADPE	1.0	1					2.0	3
ANDE	1.8	70	1.0	12	1.0	14	1.8	47
ARMA3	1.4	16			1.5	3	2.4	69
ASCA3	2.3	16					2.0	6
ATFI	1.6	7			1.0	3	2.0	6
BLSP	1.1	6	1.5	24	1.0	5		
CASC2	1.6	19			1.3	5		
CLUN	1.8	41	3.0	18	1.5	17	1.0	3
COCA	2.8	34	3.3	35	1.5	17		
DIFO	2.0	2					1.3	8
DIHO	1.5	38			1.0	3	1.7	28
DRAU2	1.7	2						
FESU	1.7	4			1.0	2	1.6	14
GATR	1.6	45			1.1	11	2.0	33
GOOB	1.1	38	1.0	12	1.1	39	1.0	17
GYDR	1.0	1						
HIAL	1.4	30	1.0	6	1.3	9	1.5	61
HYTE	0	0						
LAPO	2.0	4			1.0	2	11.0	22
LIBO2	5.4	54	6.4	71	5.0	47	2.1	28
LYAM	1.0	1						
MADI2	1.4	6	2.3	18				
MOSI	1.1	6			1.0	2		
NEPA	1.3	2					1.0	17
OSCH	1.7	15	1.0	6			1.3	17
OSPU	1.0	3			1.0	2	1.4	14
OXOR	1.5	3	2.0	6				
POMU	2.8	67	1.5	65	1.7	41	6.1	75
PTAQ	4.7	51	1.7	41	1.8	19	13.8	28
PYSE	1.2	9			1.3	9	1.0	3
SMRA	1.3	21			1.3	6	1.2	50
SMST	3.9	53	1.3	18	1.1	17	1.9	25
SYRE	1.5	1					1.5	17
TITR	2.1	43	1.2	35	1.1	28		
TOME	1.0	3						
TRLA2	1.9	47			1.5	17	2.0	86
VAHE	2.7	55	1.8	29	1.4	13	2.9	33
VIOR2	2.0	29			1.0	3	1.0	8
VISE	1.9	45	1.0	12	2.4	52	1.7	25
XETE	3.2	4	5.3	35	1.2	8	2.0	3
MOSS	29.9	99	37.2	94	37.2	97	37.6	97
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS

	TSHE/ATFI		TSHE OPHO/POMU		TSHE/POMU		TSHE/TITR	
#PLOTS	8		17		16		26	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
MATURE TREES								
ABAM	2.0	13	6.0	6			3.0	15
ABGR	5.0	13					1.5	7
ABPR			1.0	6			5.0	7
ACMA	12.0	38	4.8	28	5.5	38	4.0	15
ALRU	12.8	63	3.4	28	6.0	31	6.0	4
ARME								
PIMO							2.0	4
POTR			1.0	6				
PSME	32.5	75	31.5	94	35.3	100	29.1	100
TABR			3.5	11	1.0	6	2.4	19
THPL	15.8	50	9.1	61	8.7	44	7.9	70
TSHE	14.0	100	17.0	83	21.9	75	16.1	89
REGENERATING TREES								
ABAM	1.0	13	2.0	11			1.9	37
ABGR			1.0	6			1.5	7
ACMA			2.0	6	1.0	19	1.3	11
ALRU	2.0	25	1.0	11	2.0	6	2.0	4
PSME	1.0	13	3.0	6	1.0	13	1.0	19
THPL	6.0	13	2.4	39	2.4	31	2.4	37
TSHE	3.7	88	6.9	72	4.3	88	6.3	93
SHRUBS								
ACCI	4.8	50	12.5	89	10.1	88	11.4	93
ACGLD			2.5	11			3.0	4
AMAL			1.0	6			2.3	11
BENE	3.3	88	6.9	78	3.6	100	7.5	89
CHME	1.0	13	1.5	11	1.7	19	1.0	30
CHUM	3.0	13	1.0	6	1.3	19	1.5	48
COCO2	2.5	25	2.0	11	2.2	31	1.4	26
CONU					2.5	13	1.5	15
GASH	2.5	25	2.0	28	3.9	63	3.6	41
HODI	1.5	25			3.0	6		
MEFE			1.0	6	1.0	6		
OECE	3.0	13	1.3	17	1.0	13		
OPHO	2.0	25	6.3	100	1.6	31	1.2	44
PAMY							1.0	4
RHPU			2.0	6	2.0	13		
RILA	2.0	25	1.0	17			1.0	4
ROGY	1.7	38	1.4	39	2.0	50	1.6	52
RUNI	1.0	13	2.3	22	1.7	19	1.0	37
RUPA	1.0	13	1.5	11	2.0	6	2.0	11
RUSP	2.0	38	1.0	28	2.5	13	1.0	26
RUUR	1.2	75	1.5	56	1.2	56	1.8	63
SARA	2.0	25	2.0	6	1.0	6		
SYMO			3.0	11	5.0	19	4.3	11
VAAL	1.0	13	3.4	28	1.0	13	3.0	37
VAME	1.0	13	2.3	17	2.0	6	2.5	37
VAOV	4.0	13	2.0	6	1.0	13	1.7	22
VAPA	3.0	63	2.2	78	1.9	81	2.5	81

Appendix 3 (cont.)

	TSHE/ATFI		TSHE/ OPHO/POMU		TSHE/POMU		TSHE/TITR	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
HERBS								
ACRU	1.0	25	1.0	28	1.0	25	1.0	15
ACTR	2.4	88	4.4	89	2.7	69	4.2	85
ADBI	2.5	25	1.9	56	2.6	44	1.5	56
ADPE	2.0	38	2.7	33	2.3	19	1.3	11
ANDE	1.0	13	1.6	44	1.8	69	1.8	70
ANLY2	1.0	13			1.5	13	1.0	4
ARMA3			3.0	6	5.0	6		
ASCA3	2.0	25	1.3	39	4.0	6	2.0	15
ATFI	5.8	100	2.9	83	1.0	31	1.4	33
BLSP	1.8	50	3.0	33	1.5	38	1.2	37
CASC2			1.5	22	3.0	19	3.7	11
CLUN	1.0	38	1.4	44	1.5	25	2.1	59
COCA	2.0	13	2.1	39			2.0	41
DIFO	3.7	38	1.2	28	2.0	6	2.0	4
DIHO	1.0	50	1.4	28	3.0	31	1.8	44
DRAU2			1.8	28	1.0	6	1.0	15
GATR	2.3	75	1.4	67	2.9	44	1.3	44
GOOB	1.0	13	1.3	39	1.0	13	1.1	26
GYDR			4.3	22	2.0	6	3.4	19
HIAL			1.0	17	2.8	25	1.1	30
HYTE	10.0	13	1.0	22				
LAMU			1.0	6	2.0	6		
LAPO					4.0	6		
LIBO2	3.0	25	2.1	39	3.6	31	2.7	67
LYAM			2.0	6				
MIBR	4.0	13					1.0	4
MADI2	1.0	13	1.0	28	1.5	13	1.6	19
MOSI	8.3	50	4.3	44			1.3	11
NEPA								
OSCH	2.0	25	1.3	17			1.0	4
OXOR			17.3	17	2.0	6		
POMU	22.8	100	15.6	100	10.3	100	5.0	89
PTAQ	1.5	50	1.7	33	2.3	69	1.8	41
PYSE	1.0	13			1.0	6	1.0	4
SMRA			1.0	6	1.0	13	1.0	7
SMST	2.0	13	1.4	44	2.0	25	1.7	56
TITR	2.6	88	5.3	83	1.7	63	7.3	96
TOME	4.3	38	13.5	11				
TRLA2	1.0	38	1.3	22	2.4	56	2.6	26
TROV	1.0	75	1.4	72	1.4	88	1.4	93
VAHE	2.0	75	5.3	67	2.3	56	2.9	67
VICIA								
VIOR2			1.3	17	3.0	38	2.1	33
VISE	1.0	25	1.0	28	1.5	13	1.5	30
XETE	2.0	13			1.0	6	1.0	11
MOSS	16	100	32	100	35	100	32	100
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS

	TSHE/ BENE-GASH		TSHE/GASH		TSHE/ CONU/ACTR		TSHE- PSME-ARME	
#PLOTS	42		20		10		2	
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS
MATURE TREES								
ABAM	3.0	2						
ABGR					5.0	10		
ABPR	2.0	2	1.0	15				
ACMA	3.0	24	3.0	30	4.3	30	1.0	100
ALRU	3.5	5	1.0	10				
ARME							2.0	100
PIMO			2.8	20				
POTR								
PSME	33.2	98	28.2	100	64.1	100	11.5	100
TABR	6.0	10	1.0	5	1.0	10		
THPL	6.2	48	4.2	65	10.0	10	1.0	50
TSHE	13.9	79	13.0	80	42.5	20	1.0	50
REGENERATING TREES								
ABAM	1.9	19	1.0	15				
ABGR					5.0	10		
ACMA	1.0	10	1.5	10	1.5	20	1.0	50
ALRU	2.0	2						
PSME	1.8	29	1.3	35	2.3	30	1.0	50
THPL	3.0	38	1.9	50	1.0	10		
TSHE	3.7	90	2.6	85	5.0	10	1.0	100
SHRUBS								
ACCI	9.9	79	6.2	55	29.7	100	1.5	100
ACGLD	1.7	7	3.0	5	1.0	10		
AMAL	1.0	5	1.0	5	1.0	10		
BENE	16.2	100	3.2	100	12.9	100	10.0	50
CHME	1.2	21	1.0	10	1.3	30		
CHUM	1.8	48	2.2	30	1.5	20	1.0	100
COCO2	3.3	21	3.3	15	4.0	40	1.0	100
CONU	3.8	40	2.3	30	13.3	100	1.0	50
GASH	23.4	100	34.3	100	3.0	10	70.0	50
HODI	1.5	14	1.0	5	2.0	40	1.0	50
MEFE	1.0	2						
OECE	2.0	2						
OPHO			1.0	5				
PAMY	1.4	12	1.7	15				
RHPU	1.0	10						
RILA	1.0	2						
ROGY	1.5	64	1.1	60	2.9	100	1.0	50
RUNI	1.4	12	1.0	5				
RUPA	1.3	14	1.0	10	2.3	30		
RUSP	1.0	19	1.0	15			1.0	50
RUUR	1.8	50	1.3	60	2.0	40		
SARA	2.0	2						
SYMO	1.8	29	1.7	15	2.5	80		
VAAL	1.5	5	2.5	10				
VAME	2.0	10	1.0	25	2.0	10		
VAOV	1.0	7	1.5	10				
VAPA	2.0	83	2.4	90	2.3	30	1.0	50

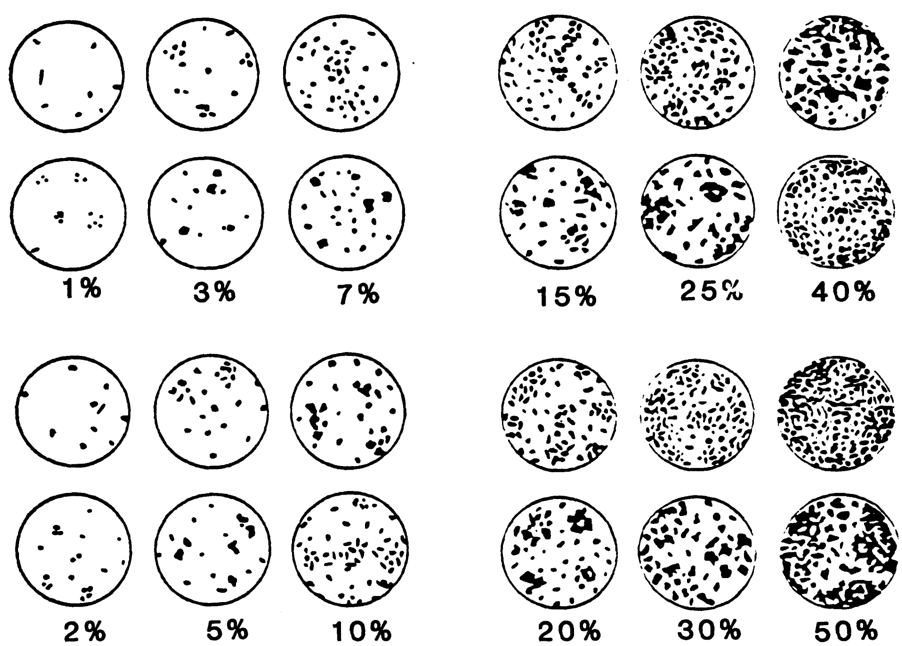
	TSHE/ BENE-GASH		TSHE/GASH		TSHE/ CONU/ACTR		TSHE-PSME-ARME	
	%COV	CONS	%COV	CONS	C%COV	CONS	%COV	CONS
HERBS								
ACRU								
ACTR	1.8	62	1.6	40	19.2	100	2.0	50
ADBI	1.2	29	2.0	10	3.9	90	1.0	50
ADPE								
ANDE	1.6	50	1.0	25	3.3	80		
ANLY2	1.0	5			1.0	10		
ARMA3	1.0	2			2.0	30		
ASCA3								
ATFI	1.0	7			1.0	10		
BLSP	1.0	7						
CASC2	1.5	5			1.6	50		
CLUN	2.3	14	1.0	5	2.2	60		
COCA	2.0	17	1.0	10	3.0	20		
DIFO								
DIHO	1.0	5	1.0	5	2.0	60		
DRAU2								
GATR	1.2	24	1.0	10	2.3	70	1.0	50
GOOB	1.0	26	1.0	20	1.5	20		
GYDR								
HIAL	1.2	14	1.0	5	2.0	10	1.0	50
HYTE								
LAMU								
LAPO	2.0	2			2.0	20		
LIBO2	1.9	62	1.9	60	2.7	30	1.0	50
LYAM								
MIBR								
MADI2	1.0	5						
MOSI	1.5	5			4.0	20		
NEPA								
OSCH	1.3	7			2.4	70		
OXOR	1.0	7	2.0	5				
POMU	2.1	52	1.2	30	2.5	80	1.0	50
PTAQ	2.0	62	2.6	70	2.3	40	1.0	50
PYSE	1.0	5						
SMRA	1.3	7			2.0	10		
SMST	1.3	17	1.5	10	1.9	80		
TITR	1.0	10	1.0	10	2.0	20		
TOME								
TRLA2	1.2	45	1.3	45	4.2	90	1.0	100
TROV	1.1	43	1.0	15	1.7	90		
VAHE	1.6	26	1.0	15	4.0	80		
VICIA								
VIOR2	1.6	48	1.3	20	2.8	90	1.0	50
VISE	1.0	17	1.3	30				
XETE	2.5	5	1.3	20	2.0	10		
MOSS	29.5	100	28	95	19	90	25	100
	%COV	CONS	%COV	CONS	%COV	CONS	%COV	CONS

APPENDIX 4

Use these charts to estimate percent cover of both understory and overstory species.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

COMPARISON CHARTS FOR VISUAL ESTIMATION OF FOLIAGE COVER 1/



1. Developed by Richard D. Terry and George V. Chilingar. Published by the Society of Economic Paleontologist and Minerologist in its Journal of Sedimentary Petrology 25 (3): 229-234, September, 1955.

APPENDIX 5

RELATIONSHIP OF FOREST ZONES TO COMPREHENSIVE MANAGEMENT PLAN WORKING GROUPS

In general, the working groups for the new Forest Plan correspond to the forest zones as defined by climax tree species. Some important differences must be noted. The Forest planning models have limits to the number of working groups which can be dealt with in the detail employed by the Gifford Pinchot National Forest planners. Therefore decisions were made to combine or separate Forest Zones according to the greatest differences which would affect the many resources modeled and the most recent mapping units available. The biological definitions of forest zones were used as defined by the Regional Ecology Programs. The major combination of zones into a working group was the addition of the Grand Fir Zone to the western hemlock working group. The working groups also include areas mapped by dominant canopy tree species which sometimes do not correspond to climax tree species used to delimit the forest zones. The Forest Zone composition of the working groups is as follows:

WORKING GROUP	FOREST ZONE (and associated tree species)
Western hemlock	W. Hemlock, Grand Fir,& Ponderosa Pine Zones (western redcedar and Douglas-fir)
Pacific silver fir	Pacific Silver Fir Zone (lacks silver fir-mtn. hemlock mixture)
Mountain hemlock	Mountain Hemlock Zone (Engelmann spruce, Alaska yellow cedar, subalpine fir & silver fir-mtn. hemlock)
Red alder	Riparian areas and Western Hemlock Zone (black cottonwood)
Lodgepole pine	Lodgepole Pine Zone (western larch)
Subalpine fir	Subalpine Fir Zone (mixed subalpine fir-mtn. hemlock forest with alpine parkland)

KEY TO WESTERN HEMLOCK ZONE PLANT ASSOCIATIONS

See page 60 for complete instructions for the use of this key.
See Table 1 and 17 for English names of plant association species codes.
See Halverson et al. 1986 for photos and descriptions of these species.

1a	Skunk-cabbage (LYAM) cover ≥ 2%	**TSHE/LYAM**	(p 70)
1b	Skunk-cabbage cover < 2%	2	
2a	Devil's club (OPHO) cover ≥ 3%	**TSHE/OPHO/POMU**	(p 74)
2b	Devil's club cover < 3%	3	
3a	Lady fern (ATFI) cover ≥ 5%	**TSHE/ATFI**	(p 72)
3b	Lady fern cover < 5%	4	
4a	Oregon oxalis (OXOR) cover ≥ 5%	5	
4b	Oregon oxalis cover < 5%	6	
5a	Alaska huckleberry (VAAL) cover ≥ 3%	**TSHE/VAAL/OXOR**	(p 78)
5b	Alaska huckleberry cover < 3%	**TSHE/POMU-OXOR**	(p 76)
6a	Coolwort foamflower (TITR,=TIUN) plus inside-out flower (VAHE) cover ≥ 5%	**TSHE/TITR**	(p 80)
6b	Coolwort foamflower & VAHE COVER < 5%	7	
7a	Alaska huckleberry (VAAL) cover ≥ 5%	8	
7b	Alaska huckleberry cover < 5%	9	
8a	Salal (GASH) cover ≥ 5%	**TSHE/VAAL-GASH**	(p 88)
8b	Salal cover < 5%	**TSHE/VAAL/COCA**	(p 86)
9a	Swordfern (POMU) cover ≥ 10%	10	
9b	Swordfern cover < 10%	11	
10a	Dwarf Oregon grape (BENE) cover ≥ 10%	**TSHE/BENE/POMU**	(p 84)
10b	Dwarf Oregon grape cover < 10%	**TSHE/POMU**	(p 82)
11a	Madrone (ARME) cover ≥ 2%	**TSHE-PSME-ARME**	(p 105)
11b	Madrone cover < 2%	12	
12a	Oceanspray (HODI) cover ≥ 3%	**TSHE-PSME/HODI**	(p 102)
12b	Oceanspray cover < 3%	13	

13a	Vanillaleaf (ACTR) cover ≥ 10%	14
13b	Vanillaleaf cover < 10%	15
14a	Dogwood (CONU) cover ≥ 10%	**TSHE/CONU/ACTR** (p 100)
14b	Dogwood cover < 10%	**TSHE/ACTR** (p 90)
15a	Salal (GASH) cover ≥ 10%	16
15b	Salal cover < 10%	17
16a	Dwarf Oregon grape (BENE) cover ≥ 10% . . .	**TSHE/BENE-GASH** (p 95)
16b	Dwarf Oregon grape cover < 10% . . .	**TSHE/GASH** (p 97)
17a	Mesic site herbs (ACTR+ADBI+ANDE+COCA+SMST+VAHE+TITR*) cover ≥ 5%	18
17b	(ACTR+ADBI+ANDE+COCA+SMST+VAHE+TITR*) cover < 5%	19
18a	Dogwood (CONU) cover ≥ 10%	**TSHE/CONU/ACTR** (p 100)
18b	Dogwood cover < 10%	**TSHE/ACTR** (p 90)
19a	Dwarf Oregon grape (BENE) cover ≥ 10%	**TSHE/BENE** (p 93)
19b	Dwarf Oregon grape < 10% : go back to #1 ease up on cover decision criteria use relative cover instead of absolute canopy cover	

If the plot does not fit the association description go back to the beginning of the key and check each choice carefully. Be sure you have taken the corect dichotomy.

* vanillaleaf (ACTR), pathfinder (ADBI), three-leaved anemone (ANDE) dogwood bunchberry (COCA), star-flowered Solomens seal (SMST), inside-out flower (VAHE), coolwort foamflower (TITR, =TIUN)